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# LA RELAZIONE FRA ALCUNE VARIABILI MACROECONOMICHE E I MERCATI AUTOMOBILISTICI EUROPEI: UN'ANALISI DI COINTEGRAZIONE

***The link between some macroeconomic variables and the European automobile markets: a cointegration analysis***

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# Abstract

The recent global financial crisis has created significant drops in automobile sales in all European markets, especially for those countries that are affected mostly by long-term structural problems and are not safeguarded against persistent demand contractions. This thesis analyses the extent to which macroeconomic variables – inflation rate, GDP per capita, oil price and interest rate – affect the amount of passenger cars' registrations both from an aggregate and a country-level point of view. Long and short-term correlation among variables is investigated by using VAR and VECM methods. For this purpose, annual data from 1990 to 2015 are used. The cointegration analysis indicates that there is evidence of a long-term equilibrium in levels of car registrations only in France. The reactivity of short-term deviations of macroeconomic variables to restore the long-term stability is equal to 60%. Results for data on Italy show that, in the long-run, car registrations do not include an error correction model based on the selected macroeconomic variables. However, there is evidence of a long-term equilibrium relationship for the levels of inflation rate, with car registrations and GDP per capita accounting for respectively 24% and 12% of the variance of annual changes in the inflation rate. Empirical results about Spain reveal that, in the long-run, car registrations do not follow a long-term equilibrium relationship based on short-run deviations of the macroeconomic variables. The estimation of two long-term equations indicates that the impact of the recent financial crisis over passenger cars' registrations outweighed the constant increase in the levels of GDP per capita in Spain.

With respect to short-run dynamics, data for Germany and UK show some evidence of the existence of a credit channel transmission that had a positive effect over the aggregate demand for new passenger cars.


*Keywords: European automobile market, VAR, VECM, Cointegration, Macroeconomic variables.*

# Riassunto

La recente crisi finanziaria ha creato significativi cali nelle vendite di automobili in tutti i mercati europei, specialmente in quei Paesi che sono maggiormente caratterizzati da problemi strutturali di lungo periodo ed esposti ad improvvise riduzioni della domanda interna. In questa tesi si analizza la misura in cui le variabili macroeconomiche – tasso d’inflazione, PIL pro capite, prezzo del petrolio e tasso d’interesse – influenzano le immatricolazioni di automobili sia a livello europeo che nell’ottica di singolo Paese. Al fine di studiare le relazioni di causalità sia nel lungo che nel breve periodo, vengono applicate le metodologie VAR e VECM. I dati utilizzati hanno frequenza annuale e coprono l’arco temporale 1990-2015. L’analisi di cointegrazione indica che il livello di immatricolazioni in Francia tende a seguire un meccanismo a correzione d’errore tale per cui ogni squilibrio di breve periodo dovuto a deviazioni delle variabili macroeconomiche viene riassorbito con una reattività pari al 60%. Inoltre, i risultati mostrano che l’andamento delle immatricolazioni di auto in Italia non include un termine di correzione basato sulle variabili macroeconomiche selezionate. Tuttavia, vi è evidenza di una relazione di equilibrio di lungo periodo riferita al tasso d’inflazione in Italia che dipende dalle deviazioni di breve periodo delle variabili immatricolazioni e PIL pro capite. Quest’ultime contribuiscono rispettivamente per il 24% e il 12% alla previsione della varianza del tasso d’inflazione stesso. I risultati relativi ai dati per la Spagna rivelano che le immatricolazioni d’auto non seguono un equilibrio di lungo periodo basato sulle deviazioni di breve periodo delle variabili macroeconomiche. La stima di due equazioni di lungo periodo indica che l’impatto della recente crisi finanziaria sulle immatricolazioni di auto è prevalso sull’incremento costante del PIL pro capite in Spagna.
Infine, per quanto riguarda le dinamiche di breve periodo, le stime per la Germania e il Regno Unito suggeriscono l’esistenza di un canale di trasmissione dalla politica monetaria che ha avuto un effetto positivo sulla domanda di automobili.

*Parole chiave: mercato automobilistico Europeo, VAR, VECM, Cointegrazione, variabili macroeconomiche.*

# Introduction

It is widely accepted that the automobile market is probably one of the most valid markets for assessing the degree of health of a certain macroeconomic environment. In broad terms, the automobile industry represents the engine of an economy since it moves people that could have access to education, health and employment; it delivers goods and services that help our daily life; it serves the community with the provision of public services like postal, waste and emergency services. Its structure has modelled in relation with several historical, socio-economic and political conditions that have contributed to the birth of many vertically integrated companies mainly focused on production and R&D expenditure. If one thinks about the diffusion of passenger vehicles (PV), it can be easily stated that the transportation infrastructure and the whole automotive business deeply affect the entire economy of a country. According to McAlinden et al. (2003), in the U.S. the demand for vehicles comes right after the demand for houses.

The motor car dates back at the rise of Fordism in the first half of the $20^{th}$ century. Labour was scientifically organized and workers were fully employed in a standardized line production (the assembly line) where tasks were rationalized. In doing so, huge economies of scale were achieved thanks to the increase in the marginal productivity per worker (output per unit of time). The Model-T Ford was produced from 1908 to 1928 and became the core product sold among the population. However, with the outbreak of the three oil crises in the $70_s$ and $80_s$, new production paradigms born with the aim of finding solutions to the increasing saturation of global automotive markets. Toyotism began to acquire favour in the last century, with the purpose of minimizing resources' waste (time and capital) and making production lean. Therefore, Japanese automakers began to acquire higher levels of market shares within European and American automobile markets. The work of Barber et al. (1999) focuses on the substantial increase in the quantities of automobiles sold in the US automobile market by Japanese automakers during the 1973-1994 period. According to their results, macroeconomic shocks accounted nearly for 10-20% of car sales evolution and the correspondent market shares' composition within US automobile market.

Nowadays, the European car industry is facing a sort of transition period in which companies are suffering for lack of demand and overcapacities of production. These are the deeply rooted structural problems which were naturally amplified by the outbreak of the recent financial crisis. Surplus production capacity is the perennial problem that affects EU automotive industry and it is due to different reasons. Firstly, the market has already reached its maturity because of the high level of specialization and differentiation of production in line with the increasing heterogeneity of customers' preferences. On the other side, the macroeconomic environment plays an important role in determining the choices of consumption and the consequent production allocation by automakers.

Therefore, as stated by Barber et al. (1999), the automobile industry is a valid object of interest for conducting a significant analysis. Firstly, the automotive market is characterized by its strong and constant oligopolistic competition with few major players that compete on an international level. Therefore, unlike other industries, one can easily compare almost the same market and macroeconomic structure by taking an instantaneous picture across different periods. Secondly, European automakers represent very important employers in the European manufacturing sector. A research jointly conducted by Unioncamere and Prometeia (2015) reported that German premium groups employ about 70% of total labour force in their headquarter country. Finally, it is largely acknowledged that macroeconomic indicators are important in determining the success of automobile players within the relative competitive arena.

This thesis conducts an analysis based on a dynamic model in the context of the European automobile market. The aim is to stress the impact of the most important macroeconomic factors over the automobile industry in order to assess the weight of environmental conditions over such an important sector of the economy. For this purpose, a structural model expressed as a vector autoregression (VAR) represents the basis for the empirical analysis. Moreover, the standard time-series analysis procedure passes through the fundamental cointegration analysis and, in case of evidence of some long-term relationships, it ends with the determination of a vector error correction model (VECM). This approach enables to draw conclusions about the direction of causality among the selected variables both in the long and in the short-term. Additionally, two econometric techniques – Impulse-response analysis and Forecast error variance decomposition – are used for measuring the magnitude of unexpected shocks in the macroeconomic indicators over the amount of passenger car registrations. This last step is essential for discriminating between the role of macroeconomics and specific firms' strategies in the evolution of the European automobile markets.

Furthermore, the same standard procedure is applied in a country-level perspective. In particular, the relationship between the automobile market and macroeconomic variables of Germany, UK, France, Italy and Spain is investigated. The aim is to assess to what extent macroeconomic variables drive the automobile markets in the countries that mostly contribute to car registrations in Europe.

Annual data from 1990 through 2015 are used for the empirical estimation of the models. Gretl software was used for all the econometric estimations.

This work is organized as follows. Chapter 1 discusses the overall current structure of the European automobile market. Chapter 2 reviews previous literature by focusing on works that have empirically verified the relationship between macroeconomic indicators and the automobile market. Chapter 3 presents data and develops the model framework. Then, the simplest multivariate OLS equation is estimated. Chapter 4 presents the empirical approach for the analysis and reports correlation matrix and some useful plots. Chapter 5 presents the results for the European automobile market by stressing the importance of long-term and short-term dynamics. Chapter 6 reports the results for each single selected country. The last paragraph conducts the final considerations.

# 1. The European automobile market: an overview

The automobile market is the prototype of impure oligopoly, in which few producers act (the lack of competition) by producing a differentiated product (the second source of market power). Automobile producers are part of some heterogeneous structured groups that compete over an international and multi-level dimension. The complexity of this market is given by its pyramid structure with a relatively low number of car manufacturers, a correspondent large number of suppliers and thousands of small and medium-sized companies ($SME_s$) which are involved in several functions. From up-stream to down-stream level, staff is involved in vehicle assembly, production, testing, sales/marketing, financing, distribution, maintenance, recycling and disposal. In this context, the accumulation of capital and qualified labour force are determinant for maintaining the relative market share and possibly conquering new customers.

During the last two decades, there have been some changes in these groups' compositions justified by the need of experimenting new partnerships in order to benefit from economies of scope/scale and exploit the correspondent synergies. Merger is quite frequent in such a highly competitive marketplace, partly because it's a strategy aimed at increasing the cost of investments in fuel efficiency, connectivity, autonomous driving and electrification.

In this preliminary chapter, fundamental traits of the European automobile market are provided by going through its evolution during the most recent years. For this purpose, several figures will be presented in order to express both the strength and the inner contradictions of such a relevant industry. For the sake of precision, the automotive sector is meant as the aggregation of cars, trucks and buses (or, in general, motor vehicles).

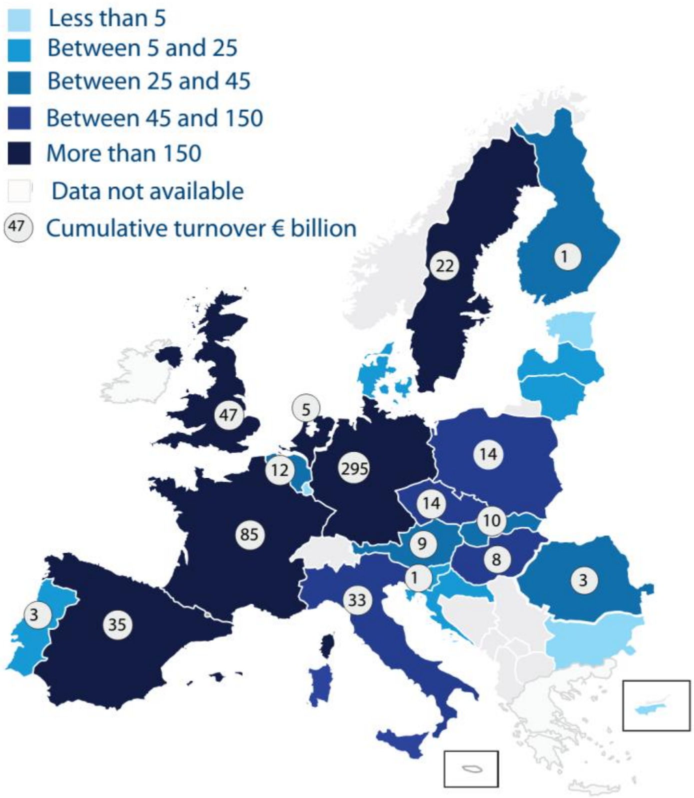
This chapter is organized as follows. The first paragraph presents a detailed description of the European car market's structure by going through demand and supply determinants. Afterwards, a picture of the degree of trade openness of the reference market is provided, with particular interest to the EU's position with respect to the rest of the world. The last paragraph adopts a critical perspective that will be functional for the following empirical investigation.

### 1.1 Economic growth, production and sales distribution

*Turnover, value-added, employment in EU*

EU automotive industry is determinant for the entire EU economy. Its turnover represents 6.3% of total EU's GDP[1]. During the period after the crisis, total value-added went from 202€ billion in 2008 down to 152€ billion in 2009, and back up to 189€ billion in 2010 and 211€ billion in 2011. According to Haugh et al. (2010), it can be identified a sort of multiplier effect of the automobile industry in proportion to the rest of the economy. Its value is close to 3 in G7 countries, higher than the aggregated indicator for the average across industries (2.2). This figure states that a 1$ increase in value-added tends to increase output by a factor of 3$. In Figure 1, the number of enterprises manufacturing motor vehicles and the relative cumulative turnover for each country are reported. Turnover is referred as the total price invoiced, including all duties, taxes, transport, packaging costs (excluding VAT).

**Figure 1: Number of automotive companies and turnover**




*Source:* Claros, EU Car Industry, 2013.

[1] The following data are from ACEA's Data Section. ACEA (European Automobile Manufacturers' Association) embodies 15 major EU car, bus and track manufacturers, which account for almost 95% of EU automotive production.

Although the automobile industry is capital-intensive industry with a relatively high capital-to-labour ratio, the percentage of labour force is quite high. According to the European Commission, around 12.1 million people are employed in the sector (which represents 5.6% of EU's workforce). The sector directly employs 2.3 million persons involved in manufacturing, being 10.4% of EU's manufacturing employment (1% of total EU's workforce). This direct labour force is split in the skilled or semi-skilled manual work (two thirds of the total) and the professional workers, such as engineers, IT, quality control (one third). Moreover, an additional 9.8 million is employed in closely related jobs, split in 4.3 million in sales and maintenance and 4.8 in transportation.

Table 1, which reports the fraction of car industry employees over total manufacturing, clarifies the proportion of car industry employees at a country-level perspective during the after-crisis years.

**Table 1: Car industry employees as a percentage of total manufacturing**

| | 2008 | 2009 | 2010 | 2011 | | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|
| BE | 6% | 6% | 6% | 6% | BG | 2% | 2% | 2% | 2% |
| CZ | 9% | 8% | 11% | 12% | DK | 1% | 0% | 1% | 1% |
| DE | 11% | 11% | 10% | 11% | EE | 3% | 2% | 3% | 3% |
| ES | 6% | 6% | 6% | 7% | FR | 8% | 8% | 7% | n.a. |
| HR | 1% | 0% | 1% | 1% | IT | 4% | 4% | 4% | 4% |
| CY | 1% | 1% | 0% | 0% | LV | 1% | 1% | 1% | 1% |
| LT | 1% | 1% | 0% | 0% | HU | 10% | 9% | 10% | 9% |
| NL | 2% | 2% | 2% | 2% | AT | 5% | 4% | 4% | 4% |
| PL | 6% | 6% | 6% | 6% | PT | 4% | 4% | 4% | 4% |
| RO | 8% | 9% | 10% | 11% | SI | 6% | 6% | 6% | 6% |
| SK | 13% | 12% | 11% | 12% | FI | 1% | 1% | 1% | 1% |
| SE | 10% | 9% | 10% | 10% | UK | 5% | n.a. | n.a. | 4% |

*Source:* Claros, EU Car Industry, 2013.

The major employers countries in 2010 were Germany (709000), France (220000), Italy (169000), UK (135000), Spain (126000), Poland (115000) and Czech Republic (106000). A further highlight that arises from the previous chart is the significant increase in automotive employees in the East-European countries due to the wide possibilities offered by lower burden of labour cost.

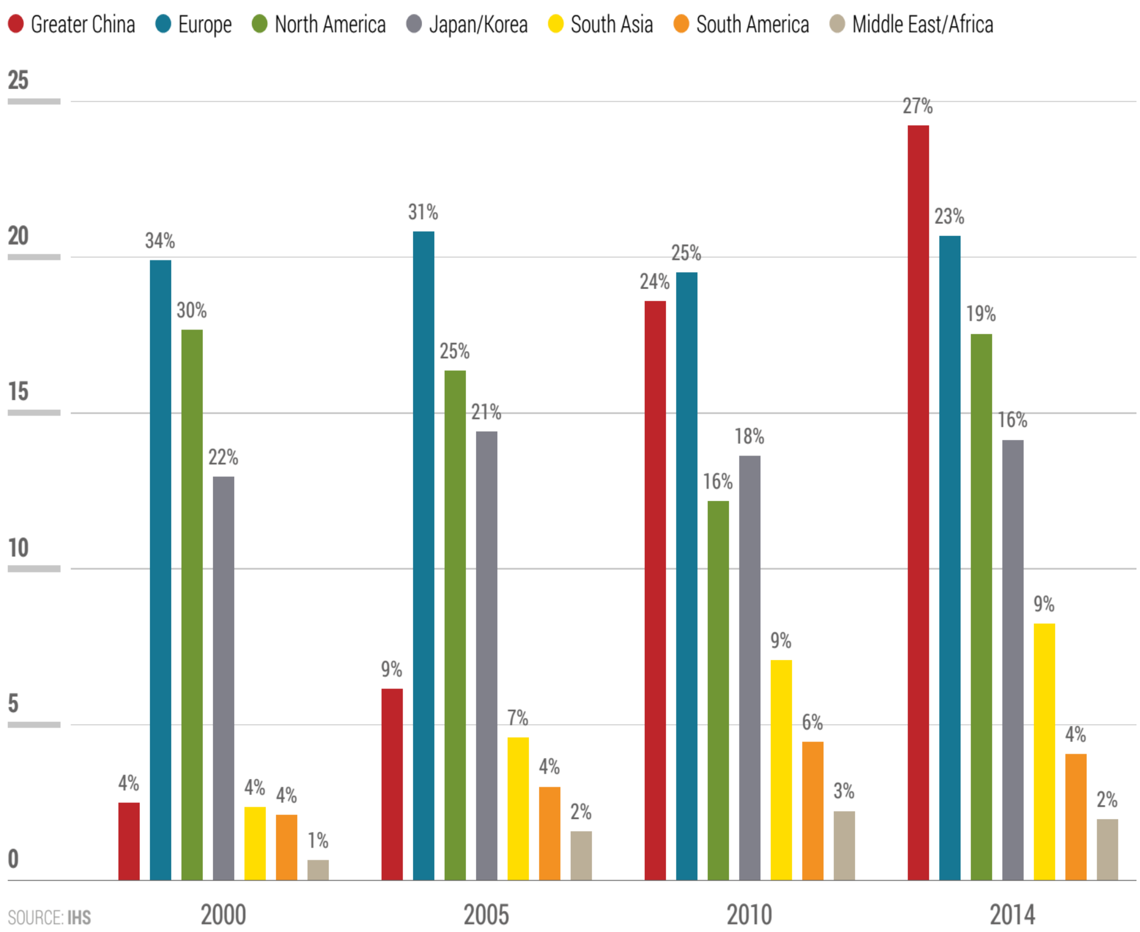
*Production and facilities in EU*

According to the ACEA Pocket Guide (2015), 90.6 million motor vehicles of which 72.3 million passenger cars were produced worldwide in 2014. Since 2001, EU has produced almost 15 million units passenger cars per year (21% of all cars in the world) coming right after China, whose production has increased at very fast rates of growth until the overtaking in 2012.

Figure 2 provides an overview of world production proportions' evolution during 2000-2014 period. Blue histograms reveal a smooth drop in European car production, while red histograms show a very rapid growth in Chinese car manufacturing.

Pie chart in Figure 3 reports the current state of global production, with China and Europe jointly covering half of the entire world passenger cars' production.

**Figure 2: World motor vehicle production in million units**




*Source:* ACEA, The automobile industry Pocket Guide, 2015.

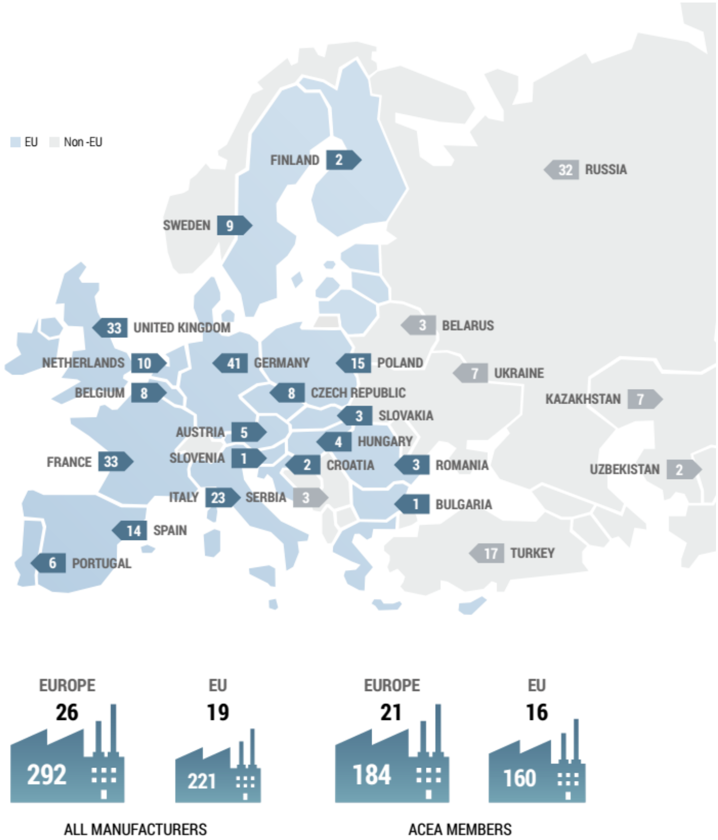
**Figure 3: World Passenger Cars Production**


Source: ACEA, The automobile industry Pocket Guide, 2015

As a whole, there are 292 factories throughout Europe, with members of ACEA managing 184 plants.

Figure 4 reports the distribution of EU's car plants. Germany, France, UK and Italy lead EU in this particular ranking, satisfying 85% of EU's car purchases.

**Figure 4: EU's automotive production distribution**




*Source:* ACEA, The automobile industry Pocket Guide, 2015.

Despite of a remarkable performance as a whole, European car industry hides a long-term surplus of production over demand, which has been estimated at around 15% in average terms. In particular, Italy (30%), Spain and France (20% each) are the countries that lead this particular ranking and were deeply hit by the recent financial crisis, as reported in Table 2.

**Table 2: Passenger vehicle production levels and growth**

| Country | 2007 | 2008 | 2007-08 | December 2008 to May 2009 |
|---|---|---|---|---|
| | Levels (thousands) | | Growth (per cent) | |
| US | 10546 | 8503 | -19.4 | -33.4 |
| Japan | 9945 | 9916 | -0.3 | -17.8 |
| Germany | 5709 | 5527 | -3.2 | 8.7 |
| France | 2551 | 2146 | -15.9 | 2.9 |
| Italy | 911 | 659 | -23.4 | |
| UK | 1535 | 1447 | -5.7 | -8.1 |
| Canada | 1565 | 1633 | 4.3 | -13.9 |
| Spain | 2196 | 1943 | -11.5 | |
| Korea | 3723 | 3450 | -7.3 | 1.0 |
| Mexico | 1209 | 1241 | 2.7 | |
| Turkey | 635 | 622 | -2.1 | |
| Brazil | 2391 | 2561 | 7.1 | |
| China | 6381 | 6738 | 5.6 | |
| India | 1713 | 1830 | 6.8 | |
| Russia | 1289 | 1469 | 14.0 | |

*Source:* Haugh et al., 2010.

**Table 3: Capacity utilization rate in EU Member States**

| Member State | Manufacturers | Capacity Utilisation (2009) |
|---|---|---|
| Germany | BMW, Daimler, VW, GM (Opel), Ford | 80% |
| Hungary | VW | 78% |
| Poland | Fiat, GM, Toyota | 74% |
| Czech Republic | VW, Toyota-PSA, Hyundai-Kia | 70% |
| Spain | PSA, Renault, VW, GM | 69% |
| UK | BMW, Jaguar & Land Rover, Toyota | 64% |
| Italy | Fiat | 57% |
| France | PSA, Renault, Toyota | 53% |

*Source:* Lee-Makiyama et al., 2012.

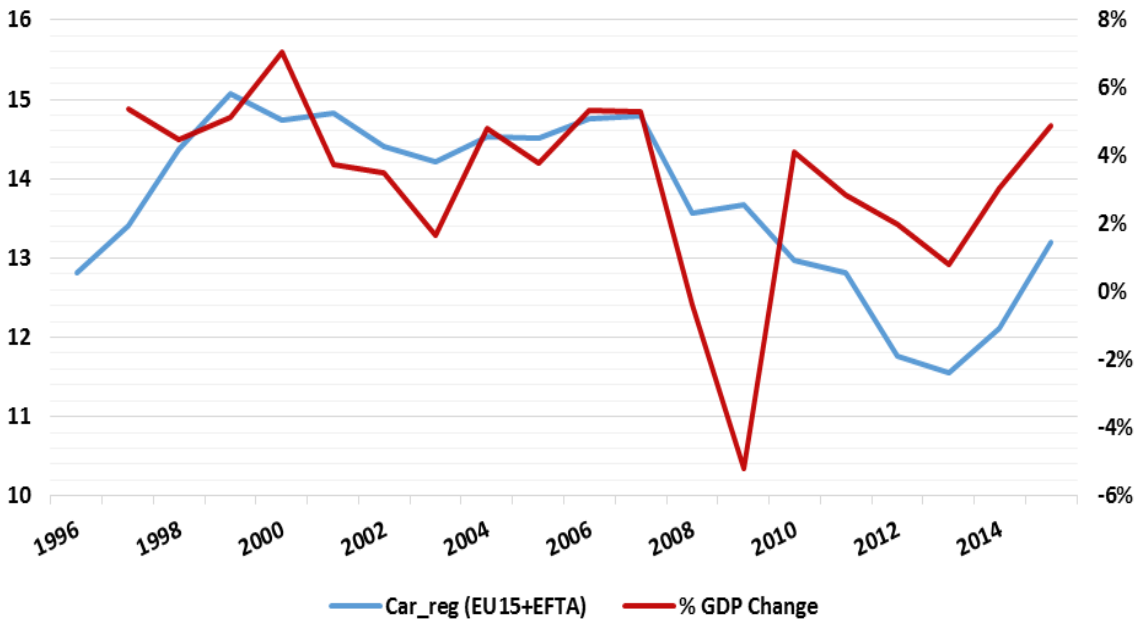
Table 3 reports the capacity utilization rate in some EU member states in 2009, which is measured as the ratio between the sales orders and the production capacity. Nowadays, production tends to be centralized in Germany and in new member states (NMS) of Eastern Europe, where companies have invested in very efficient and modern plants. This trend tends to reduce France and Italy competitiveness since production is generally spread among small and low cost-efficient plants, unable to adapt to demand evolution. In particular, Fiat, Renault and PSA were hit mostly by the crisis. As argued in the following paragraph, low shares of exports towards international markets play a relevant role in weakening the structural conditions of these companies, which are focused on the production of low-profit segments' cars.

*Sales and vehicles in use*

In 2015, 89.1 million vehicles were registered worldwide, with an increase of 2% over 2014. China leads the ranking with almost 25 million registrations (+5.3%) while Europe registers 18.7 million vehicles, being 14.2 million the cars' registrations (+9.2% over 2014). In particular, Germany registered 3.2 million cars (+5.6%), followed by UK with 2.6 million (+6.3%), France with 1.9 million (+6.8%) and Italy with 1.5 million (+15.8%).

According to Gaspareniene et al. (2014), the automobile industry moves along economics. As shown in Figure 5 – which reports the evolution of GDP annual rate of growth (on the right vertical axis) and new automobile registrations in millions (on the left axis) during the last two decades – the automobile industry seems to move in line with the overall business cycle. Trends seem to follow a similar path, especially from the outbreak of the automobile market crisis in 2010.

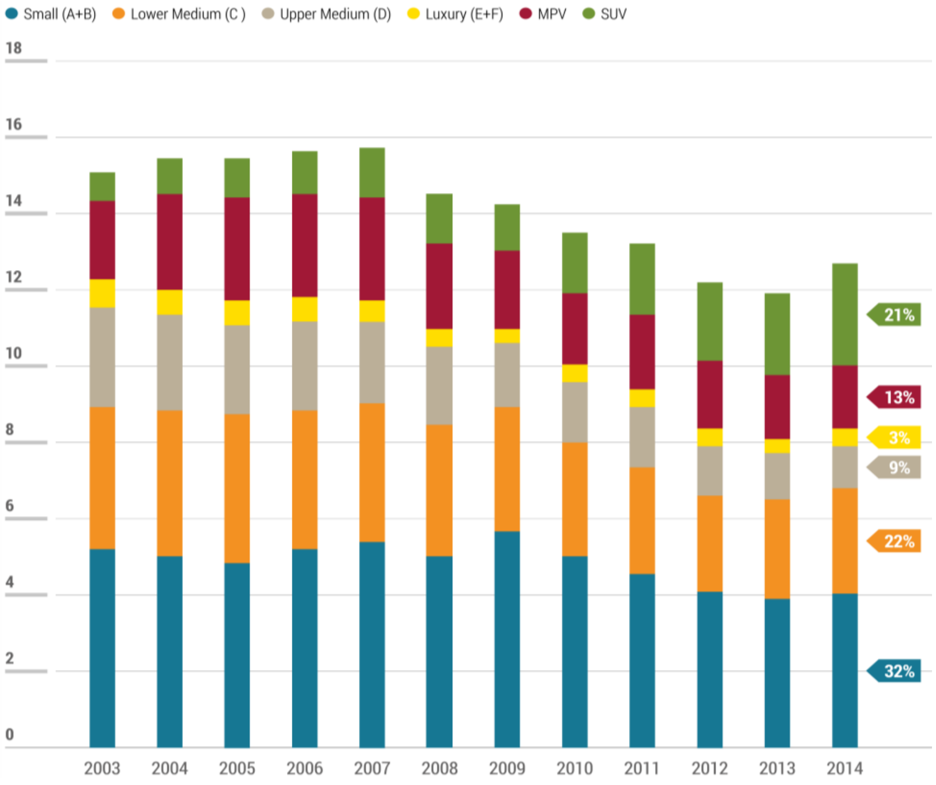
**Figure 5: Car registrations in million and percentage annual GDP growth in Europe**




*Source:* Author's own elaboration. Data from ACEA and Eurostat Databases.

Figure 6 shows the structure of European cars distribution based on the type of segment of the market. The small and the medium segments make up over half of the entire EU car market. On the contrary, medium and high premium brands mainly export their production abroad. New passenger cars are measured in million units while bars represent the percentage share over the total.

**Figure 6: New passenger cars sold in EU by segment**

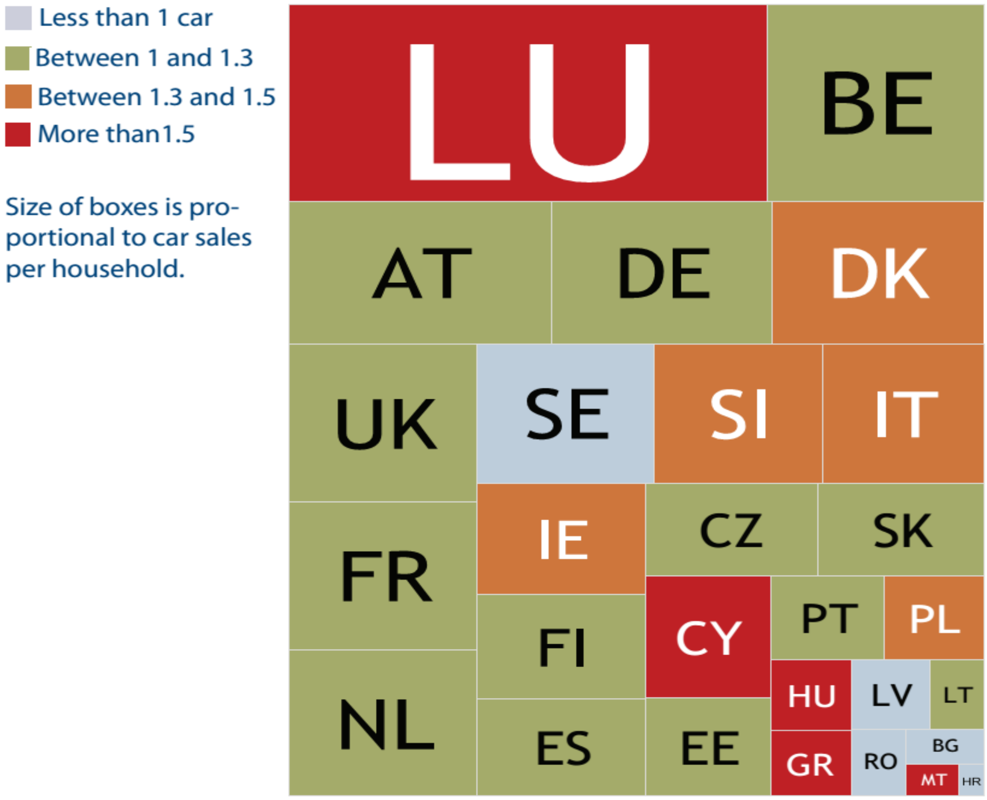



*Source:* ACEA, The automobile industry Pocket Guide, 2015.

The research by Claros (2013) stresses the role of automobile ownership. The analysis of Figure 7 leads to the definition of two important indicators. The first one, represented by colours, is car ownership ratio and it measures the number of cars that a single household owns on average (a stock measure). The second figure is car sales per household, represented by the size of the squares, and is viewed as the proportion of households that bought a new car in that year.

According to the research, the EU car ownership ratio was 1.2 cars per household on average terms. Greece reported the highest value (1.82), followed by Malta (1.68), Cypro (1.65), Luxemburg (1.62) and Italy (1.49). As regards car sales per household, Luxemburg leads the ranking (23%) followed by Belgium (11%).

**Figure 7: Car sales and cars owned per household**



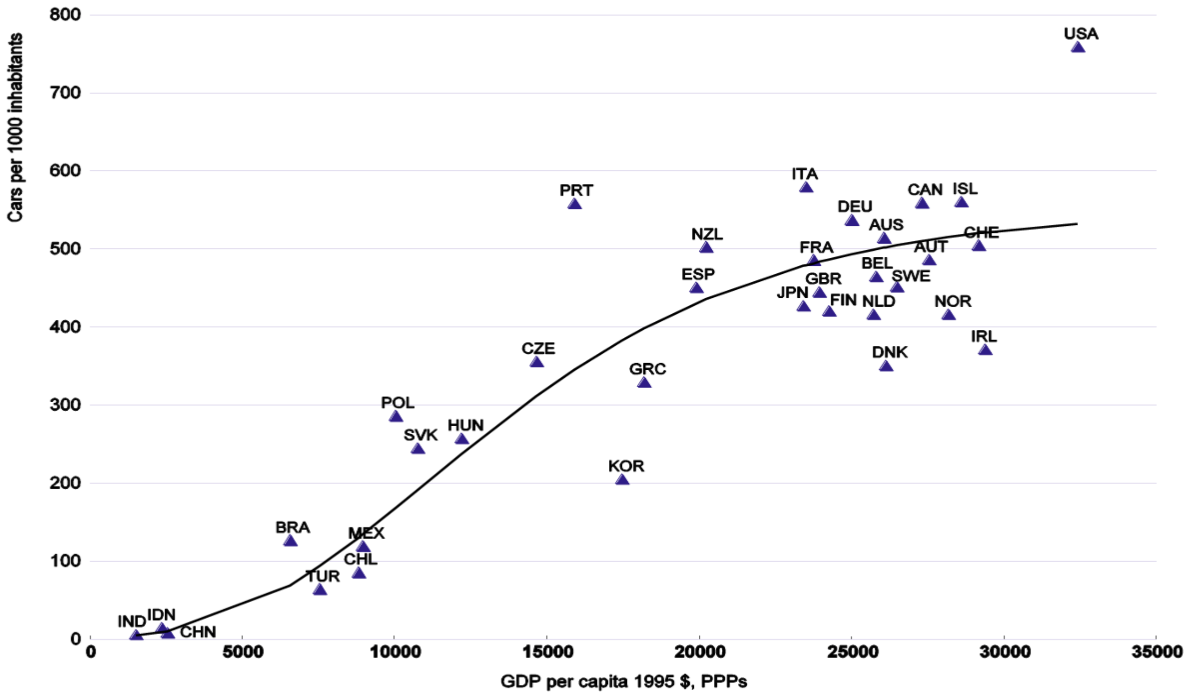

*Source:* Claros, EU Car Industry, 2013.

One can conclude that we're dealing with a very mature domestic market in which the aggregate demand has been flattening and new vehicles sales consist mostly in cars' replacement. The factors behind this stagnancy were partially due to the outbreak of recent financial crisis, which has modified income distribution by depressing single household's demand for cars. As a matter of fact, a reduction in the level of income for an individual reduces the possibility of expenditures and consequently car purchases are postponed.

The analysis by Haugh et al. (2010) shows that the automobile ownership tends to rise with GDP per capita in a non-linear way. The main idea is that car ownership rises slowly with income because the country is facing the first step of its industrialization process. Then, the value increases fast at middle-income levels and finally stabilizes reaching maturity. According to Lee-Makiyama et al. (2012), the value of income elasticity to car purchases has been estimated at factor 0.4. This means that, given a hypothetical 1% increase in income, car sales will recover at less than half the rate of the EU economy on average. Whether a country reports an upper or lower level of motorisation rate, given the same value of GDP per capita, it depends on lifestyle features and general approach of citizens to mobility.

Hence, lifestyle changes play a relevant part, too. The diffusion of alternative means of transport and the decrease of their relative price (for instance, low-cost flights) have reduced potential cars purchases. From a policy perspective, these factors are not easy to be controlled. The typical instruments used to stimulate both supply and demand are producer subsidies and consumer incentives. These tools help boosting the purchase of fuel-efficient vehicles but their effect has to be monitored constantly in order to prevent some distortions in the market. Figure 8 reports amount of cars per 1000 inhabitants against GDP per capita in 1995 dollars.

**Figure 8: Car ownership and GDP per capita**



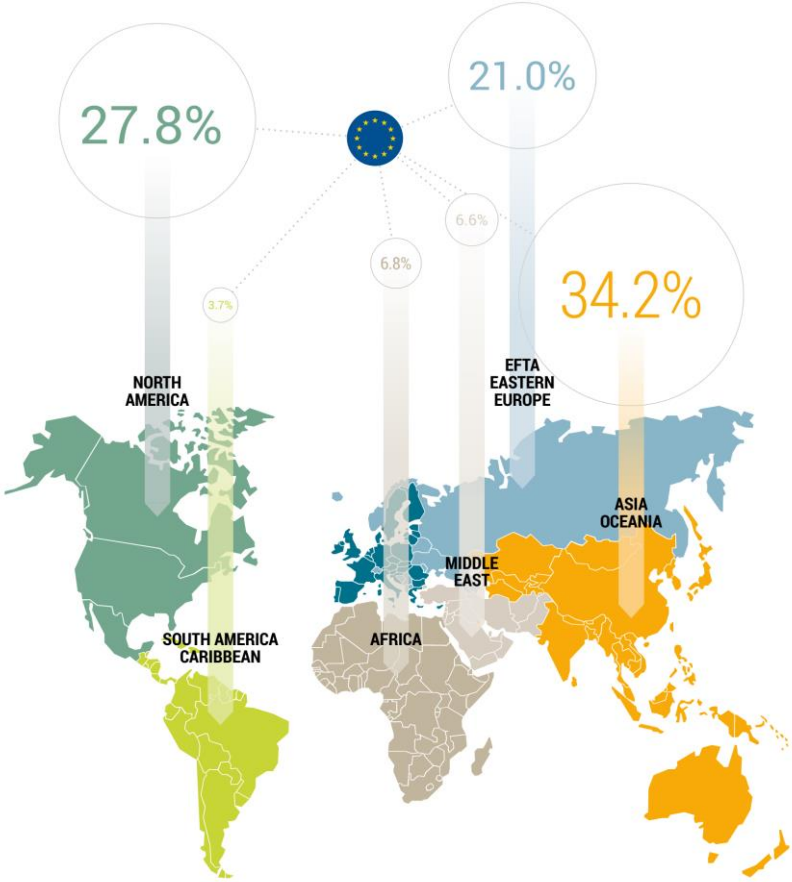

*Source:* Haugh et al., 2010.

## 1.2 Degree of openness with the rest of the world

The European car industry is one of the most successful export industries for the European economy. According to ACEA, the sector generates a large positive trade balance with the rest of the world estimated in 95.1€ billion trade surplus. Germany, Spain and France are the major net exporters of vehicles, whereas in countries like Czech Republic, Poland and Slovakia the production is much higher than domestic demand. The major amount of exports derives from sales in the higher priced (premium and large-sized) segment of the market (Audi, BMW and Mercedes). In particular, Germany is the biggest exporter of cars by producing almost 6 million cars every year and shipping abroad two thirds of the production[2]. In 2011, it exported more than 4.5 million cars especially to US and China. The percentage is high for Volkswagen group as well, since it exports about 40% of its production due to its premium Audi brand. These high numbers are the result of the high degree of specialization and comparative advantages gained on premium brands' production which basically constitute the most important proportion of EU's exports. On the contrary, the small-sized exporting countries have to struggle for maintaining their market shares in highly competitive markets all around the world.

Figure 9 shows a map of EU exports' market shares for exports of motor vehicles.

**Figure 9: EU exports of motor vehicles, value market share**




*Source:* ACEA, The automobile industry Pocket Guide, 2015.

Despite of its natural propensity to exports, the EU car industry shows a sort of resistance towards imports. Needham (2013) reports that more than 85% of cars for the EU are manufactured in Europe: Japanese imports account for 5% of the market while US has less than 3%. The reasons behind it can be summarized with the following explanations. Firstly, the low level of imports reflects the relatively high value of tariffs (around 10%, except for

[2] Data are from the report by Needham (2013).

6.5% tax for developing countries) that potentially reduce profit margins for foreign brands and are sufficient to reduce imports. For this reason, extra-EU brands currently operate on the European territory with several production and R&D facilities especially in UK, Germany and NMS. Secondly, extra-EU automakers have to bear high costs of transportation of heavy vehicles from overseas. Thirdly, strict industry standards regulation dissuade imports due to the deep heterogeneity of European consumers' tastes.

There has been some debate – Lee-Makiyama et al. (2012) – regarding the need to reduce defensive interests about car imports' penetration. However, recent talks between EU and Japan on Free Trade Agreements (FTA) have been under examination and should bring to higher level of market integration for reciprocal gains from trade, such as more investments, export efficiencies and supply chain improvements.

### 1.3 The structural problems of the European car market

As shown in Table 2 of paragraph 1.1, recent credit crunch threatened EU car industry's growth because of the decrease in macroeconomic fundamentals like GDP, consumption and trust of consumers.

Table 4 summarizes the most important factors that affect car demand trend.

**Table 4: Summary of the determinants of automobile demand**

| **Macroeconomy** | **Demographics** | **Lifestyle** | **Motorisation index** | **Vehicle costs** | **Purchase conditions** | **Policies** |
|---|---|---|---|---|---|---|
| GDP | Old age index | Approach to mobility | Amount of vehicles in use | Insurances | List price | Driving restrictions |
| Employment rate | Natality rate | Social value of car | Average longevity of vehicles | Taxes | Discounts | Envinromental protection |
| Purchasing power | Migration flows | | Motorisation rate (vehicles per 1000 inhabitants) | Fuel price | Incentives | Alternative means of transport development |
| PMI Index | | | | Mainteinance | Technology content | |
| Accidental factors such as wars, stock market crash, credit crunch, etc. | | | | | | |

*Source:* Author's own elaboration.

Europe has been suffering from a perennial surplus production capacity (almost 15% in 2012) in the automotive sector due to the maturity of its domestic market.

There has been further structural factors that have contributed to the stagnation of the European market. Above all, Lee-Makiyama et al. (2012) underline the decline of the relative productivity index, which is the result of an unbalanced relationship between the increase of average wages and value-added per worker. Basically, in the period before the outbreak of the financial crisis in 2007/08, the increase of wages was not proportionate to the increase in the produced value-added per worker. As reported in Table 5, value-added per employee in France, Italy and Spain has dropped behind those of developing countries like Brazil.

**Table 5: Pre-crisis changes in wages, value added per employee and labour productivity in the car industry**

| | Wages and Salary | | Value added per employee | | Labour productivity Index |
|---|---|---|---|---|---|
| | 2000 | 2007 | 2000 | 2007 | 2000-2008 |
| France | 28621 | 55461 | 71918 | **104092** | **-6.3%** |
| Germany | 26580 | 43707 | 53094 | 133822 | 35.7% |
| Italy | 21298 | 39895 | 41205 | **99747** | **-2.2%** |
| Spain | 24326 | 44881 | 52613 | **106628** | 14.4% |
| UK | 39253 | 68947 | 51243 | 147442 | 35.2% |
| US | 51338 | 62020 | 189997 | 280262 | 63.7% |
| Japan | 66423 | 60558 | 241975 | 290149 | 32.1% |
| Korea | 26963 | 54867 | 142385 | 250952 | 47.6% |
| Brazil | 16042 | 25653 | 53577 | **120299** | |
| China | 2798 | 6059 | 28671 | 47542 | |

*Source:* Lee-Makiyama, 2012.

Secondly, low returns from investments in innovation amplify the process of value destruction for countries like France and Italy that are not able to convert R&D spending in value-added creation. In the paper by Lee-Makiyama (2012), an OECD calculation based on the relationship between the annual growth in R&D spending in the car industry and the value-added in period between 2000 and 2008 are considered. On one side, Germany, Japan and Korea generally maintain a 1:1 parity of value-added creation, given a unit increment of R&D spending. Conversely, France and Italy report a negative correlation between the two considered variables.

Eventually, European car manufacturing industry might be split in two groups. The first group includes export-oriented countries, which have specialized in medium-high size cars' production and focus on profit maximization coming from extra-EU exports. In this way, these countries are able to face the lack of domestic demand. Conversely, the second group includes those economies that have put efforts in maximization of volumes by investing many R&D resources in non-profitable segments of the market, even without a modern infrastructure to do so.

This preliminary research has underlined the deep relationship between business cycles and automobile industry throughout European countries. There are many micro and macro-economic factors that play very important roles in economics. The aim of this thesis is to determine the magnitude of shocks in purchasing power, economic wealth, oil price and monetary policy over the structure of the European automobile market. In particular, the purpose is to study the extent to which macroeconomic variables contribute to the determination of car registrations both in the more and in the less performant countries.

Before moving to the formulation of the econometric model and the investigation of data, the next chapter overviews the most relevant studies dealing with this topic. Thus, Chapter 2 provides a solid basis for the development of the theoretical model that represents the framework of the research.

# 2. Background and literature review

The literature that investigates the relationship between macroeconomic variables and the automobile market is quite heterogeneous.

The first distinction is about the object of investigation. Many papers studied the relationship between macroeconomic variables and the level of domestic prices of imported vehicles. From this perspective, a wide area of academic research deals with the Exchange rate pass-through effect, which is defined as the elasticity of local-currency import prices with respect to the local-currency price of foreign currency. One of the most representative studies is the one by Goldberg (1995). Thus, the pass-through effect reflects the extent to which international prices respond to changes in exchange rates between exporting and importing countries.

Similarly, there is a wide area of research which focuses on data on quantity. One part investigates the factors influencing automobile production and the latter on the factors influencing automobile demand.

Table 6 overviews the most recent and relevant studies dealing with production and demand factors.

**Table 6: Summary of recent literature on the automobile market**

| The factors influencing automobile production | | The factors influencing automobile demand | |
|---|---|---|---|
| **Factor** | **Author(s)** | **Factor** | **Author(s)** |
| GDP | Madlani, Ulvestad, 2012; Haugh, et. al., 2010 | GDP | Muhammad, et. al., 2012; Ding, Akoorie, 2013 |
| Governmental policy | Madlani, Ulvestad, 2012; Drauz, 2013 | GDP per capita | Haugh, et. al., 2010; APEC Automotive Dialogue, 2002 |
| Exchange rate | Madlani, Ulvestad, 2012; Drauz, 2013 | Fuel prices | Muhammad, et. al., 2012; Busse, et. al., 2009 |
| Price of raw material | Madlani, Ulvestad, 2012; Ford Motor Company, 2012 | Interest rate | Muhammad, et. al., 2012; Haugh, et. al., 2010; Erdem, Nazlioglu, 2013 |
| Petroleum price | Ford Motor Company, 2012, Kumar, Maheswaran, 2013 | Unemployment rate | Muhammad, et. al., 2012 |
| Interest rate | Ford Motor Company, 2012 | Income level | Dargay, 2001; Smusin, Makayeva, 2009 |
| Public debt | Ford Motor Company, 2012 | Inflation | Muhammad, et. al., 2012; APEC Automotive Dialogue, 2002 |
| Demand | European Commission, 2008 | Private sector consumption | Haugh, et. al., 2010 |
| | | Petroleum price | Haugh, et. al., 2010, Abu-Eisheh, Mannering, 2002 |
| | | Financial state of the markets | Haugh, et. al., 2010, Ding, Akoorie, 2013 |
| | | Customers' (un)certainty about the future | Haugh, et. al., 2010, APEC Automotive Dialogue, 2002 |
| | | Customers' priorities | Erdem, Nazlioglu, 2013 |
| | | International trade | Erdem, Nazlioglu, 2013 |
| | | Manufacturing | Erdem, Nazlioglu, 2013; Smusin, Makayeva, 2009 |
| | | Exchange rate | Ludvigson, 1998; APEC Automotive Dialogue, 2002 |
| | | Real estate price | Smusin, Makayeva, 2009 |

*Source:* Gaspareniene et al., 2014.

As shown in Table 6, the automobile production is affected by GDP, governmental policies, exchange rate movements, price of raw materials (mainly oil and steel), monetary policy (interest rate setting), public debt and demand. On the other side, demand is caused by a higher number of factors that all affect cars purchase decisions. The most important ones were found to be the interest rate, petroleum prices and the income level.

In this thesis the factors affecting automobile demand are taken into account. This choice is in line with the work by Muhammad et al. (2013), which stresses the preminent role of the automobile demand's decrease as the main determinant of the drop in automobile production during 2008-2012.

In the work promoted by the OECD Economics Department by Haugh et al. (2010) the relationship between automobile industry and business cycles is investigated, with particular interest to the recent crisis period. They suggest a long-term error-correction model in which sales depend on GDP per capita, real oil price and financial market conditions. Data are taken from first quarter of 1996 through the last quarter of 2008 and are about the G7 countries. The aim is to demonstrate that the drop of car sales in the last quarter of 2008 is not simply attributable just to GDP and oil price, since improvement in financial conditions could determine a recovery in car sales.

$$\log(sale) = \beta_0 + \beta_1 \log(gdppc) + \beta_2 \log(roil) + \beta_3 fci \qquad (1)$$

In equation (1), *log(gdppc)* is the logarithm of Gross Domestic Product per capita and *log(roil)* is the logarithm of Real Oil Price. The Financial condition index (*fci*) is the one developed in Guichard et al. (2009), which expresses the wealth of the overall financial market by summarizing the movements of real exchange rate, real short-term and long-term interest rates, housing price, corporate bonds spreads and tightness of credit conditions. Each of these variables have a weight, whose level is determined by using a reduced form VAR and analysing quarterly data. In particular, each percentage is the result of a one-unit change of that variable on US GDP after four to six quarters, a relevant period for monetary policy decisions. On the basis of equation (1), a significant role of financial conditions has been found in all countries, except for France. Moreover, this effect seems to affect the automobile industry with very short lags, indicating a very fast speed of adjustment in the current crisis.

One of the most relevant studies is the one by Muhammad et al. (2013), which deals with the long-term causal relationship between macroeconomic variables and passenger vehicles sales in Malaysia. In this paper, car sales are function of Consumer Price Index (a proxy to inflation), Index of Industrial Production (proxy to GDP), Oil Price sold at gas stations in Malaysia and Monetary Policy Rate (proxy to interest rate of loans offered by banks). In order to apply VAR and VECM estimation methods, the authors conduct a preliminary three-steps time series analysis.

In the first step, the Unit Root Test is undertaken to investigate the stationarity degree of each variable. For this purpose, Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) are used with the aim of avoiding the presence of spurious regression problem. The authors find out that all the selected variables have the same degree of integration or stationary level of I(1).

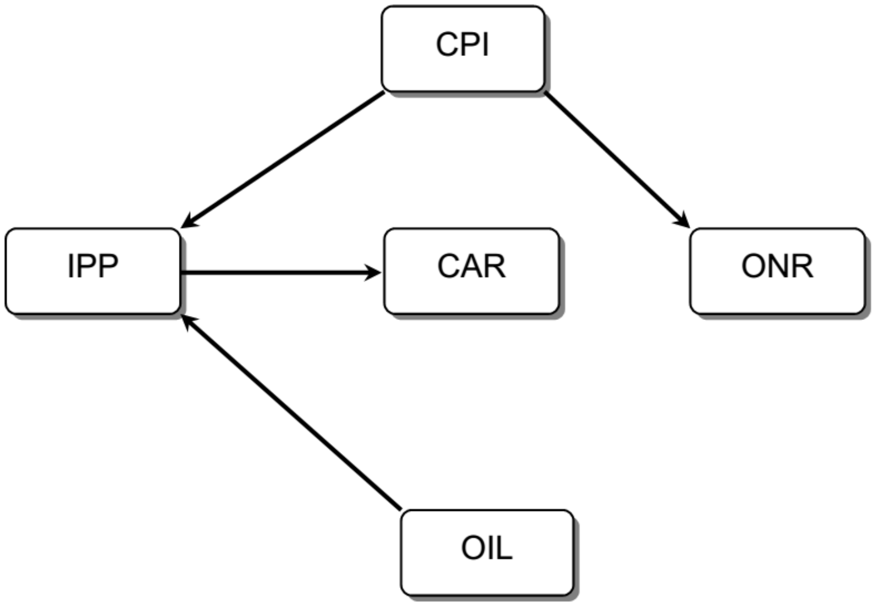
In the second step, the authors conduct the Lags Test in order to select the correct number of lags to include in the Cointegration Test and in the Vector Error Correction Model. From the Akaike Information Criterion (AIC) it emerges that the lag 2 is the appropriate one. This conclusion is strengthened by the application of VAR unit stability test, which confirms the stability of the process and the correct number of lags.

In the third step, the authors implement the Johansen and Juselius (J&J) Cointegration Test which demonstrates the presence of two cointegration relationships in the long-term. The results confirm the underlying economic theory since CPI, oil price and interest rate were negatively related with car sales while GDP was positively related with them.

Therefore, the last step is the inclusion of the error correction term (ECT) for the estimation of a Vector Error Correction Model (VECM). Its coefficients reveal that all four macroeconomic variables are long-term Granger causal to car sales. This shows that the car variable is endogenous in the model and it adjusts to the long-term equilibrium with a lag of 2. The reactivity to restore the equilibrium is reflected by the ECT parameter's estimation, which is equal to 56%. Similarly, CPI, interest rate, car sales and oil price are found to be long-term Granger causal for GDP.

Finally, the application of the Wald test allows to determine short-term relationships. Figure 10 shows the two pathways that finally affect vehicles sales in the short term. On one hand, inflation is a short-term significant factor for GDP and interest rate. On the other hand, oil price shocks affect GDP in the short term. However, only shocks to GDP are found to be short-term related with car sales. This means that factors that affect consumers' income in Malaysia will positively increase demand for automobiles in Malaysia.

**Figure 10: Granger causal short-term relationship**




*Source:* Muhammad et al., 2013.

The study by Ludvigson (1998) is focused on the relationship between interest rate and automobile sales in US. Data for the research have monthly frequency and go from 1965 to 1994. The main result of the research is that data empirically support the idea of the credit channel theory in which composition of automobile credit directly affects the final purchase of automobiles in the market. Moreover, the author defines an indicator for the specific composition of the automobile credit. This variable is called "Financial mix" and is measured as the ratio of bank automobile credit to credit issued by automobile finance companies plus bank credit. Results show that unanticipated innovations in the Financial Mix have significant effects on automobile consumption. The whole mechanism begins with a tightening in monetary policy which determines a drop in supply of consumer loans. The sequence ends with a decline in real consumption by households. These effects are found to be statistically significant. However, by going through the variance decomposition of funds rate innovation, no relevant quantitative impact of these effects is found with regard to the aggregate economy.

Dargay (2001) studies the relationship between household income and car ownership within the UK automobile market with cohort data between 1970 and 1995. The author demonstrates that the relationship is not symmetric, indicating that car ownership responds more strongly to an increase than a fall in income. It emerges that there is a kind of "stickiness" in the downward direction. This is confirmed by the fact that income elasticity is found to be different through time: it is higher when income increases while it is smaller when income drops. In qualitative terms, a general increase in aggregate income makes it easier for households to own cars. Buying and using a car becomes a habit and this trend can not be easily reversed. Initially seen as a luxury good, nowadays the car has become a necessity. This is due to the impact of social standards attributing much more value to car ownership. Finally, such dynamics confirm the idea that car ownership is progressively associated with difficulty to reduce car dependence once the saturation level is approached. Hysteresis is therefore demonstrated.

Barber et al. (1999) focused their attention on the American automobile market, with the intent of investigating the reasons of Japanese automakers' market shares gains in the period immediately after the oil shocks crises and the end of gold exchange standard era. For this purpose, they build a duopoly Cournot model of firms that operate in a complex macroeconomy hit by shocks to income, exchange rates, oil prices and further factors. The entire methodology is based on a reduced-form VAR and these are the results. Firstly, real income growth was likely to favour American automakers more than Japanese automakers, being the magnitude more pronounced in the period since 1984 to 1994. Secondly, an increase in oil price had negative implications on both American and Japanese automakers but, the effect was weaker for Japanese automakers. The exposure of American automakers was far stronger during the first period (1973-1983) and this is justified by the nature of American automotive production, more inclined to luxury category as opposed to Japanese manufacturers. Secondly, an exchange rate shock such as a yen appreciation was likely to depress Japanese automakers' sales in the US market. This last result proved the existence of the Exchange-rate pass-through effect, which showed evidence about the elasticity of US consumers to the demand for automobiles. Moreover, the authors demonstrate that the relevance of these macroeconomic effects is quite moderate since they account for nearly 20% for American automakers monthly-sales changes and for a little more than 10% for Japanese automakers.

In the research by Lee and Ni (2002) the link between oil shocks and the two sides of demand and supply is the object of investigation. This analysis considers different industries that have several levels of oil-intensity as regards cost input: they use data from petroleum refinery and industrial chemicals, automobile industry and metals, machinery, and other industries in US. The findings differ concerning the type of industry. As regards oil-intensive industries like petroleum refinery and industrial chemicals, oil price shocks mostly reduce supply following the input-cost effect theory such that "higher energy cost lowers usage of oil which in turn lowers productivity of capital and labor (p.824)". Concerning many other industries, such as the automotive one, oil price shocks mostly reduce households' demand for vehicle. In this second case, the income effect prevails. It means that higher cost of imported oil increases inflation and eventually reduces US households' real income which finally increases the possibility of delaying the purchase of durable goods.

Busse et al. (2009) study the effect of gasoline prices over market shares and prices of cars during the 1999-2008 period on the American new and the old cars' markets. As regards the new market, they report a significant correlation especially with market shares both for the fuel-most efficient quartile (20% increase) and for the fuel-less efficient quartile (24% decrease), given a 1$ gasoline price increase. This says something about the suppliers' opportunity to experience high market shares' changes and reduced margin on price setting. On the contrary, the used car market shows little correlation concerning market share. However, the effect of gasoline price over used cars' transaction prices is higher, suggesting a more rapid price adjustment for used cars. Overall, this paper stresses the role of gasoline prices on households' consumption choices.

In the research by Gasparenienne et al. (2014) the relationship between EU automobile market and macroeconomic indicators during the period of financial crisis is analyzed. The objectives of this research include (i) the specification of the factors that mostly affect automobile production and demand and (ii) the individuation of the ones that have contributed to the recession of EU automobile industry. To do so, the authors use correlation analysis and multifaceted regression analysis. Data for the analysis of production determinants are taken from 1997 to 2012. Production has been found strongly and positively correlated with new automobile registrations and GDP. These two factors can explain 60% of changes of automobile production in the EU. Similarly, production is found to have a positive correlation with public debt even if this link only reports a medium-size significance.

On the other hand, quarterly data from 2003 to 2012 are taken for the investigation of automobile demand (new automobile registrations). Interestingly, GDP and GDP per capita are not used for the research, since they do not exhibit normal distribution and can't be computed as logarithms. Test for stationarity reports that all variables are non-stationary. Despite of the first grade differentation, many variables fail to reach stationarity. Only one variable, i.e. long-term goods consumption expenditure, is found to have a relatively important positive correlation with new automobile registrations but exhibits a weak correlation (0.321).

Eventually, the analysis of automobile demand factors partially failed due to non-stationarity of variables. Although data were differentiated, this trick was not able to produce reliable results from a statistical point of view. The authors finally suggest the application of the Vector Error Correction Model (VECM) to find valuable results.

Table 7 summarizes the results of the papers mentioned above by highlighting the strength of the links between the most important macroeconomic factors and automobile demand.

**Table 7: Macroeconomic factors and automobile demand**

| Author and year | Weak link | Medium link | Strong link |
|---|---|---|---|
| Haugh et al. (2010) | | | Private consumption |
| Muhammad et al. (2012) | | | GDP, inflation, unemployment rate, interest rate |
| Ludvigson (1998) | | | Exchange rate |
| Busse et al. (2009) | | Oil price, income level, exchange rate | |
| Dargay (2001) | | Income level | |
| Gasparenienne et al. (2014) | | | Private consumption |
| Lee and Ni (2002) | | | Oil price |
| Barber et al. (1999) | | Oil price, exchange rate | GDP |

*Source:* Author's own elaboration inspired by Gasparenienne et al., 2014

The analysis of scientific research on this topic has enabled to clarify how macroeconomic environment affects the automobile market. The main point is that all these factors directly affect private purchase and use of automobiles and, indirectly, automobile production as a whole.

Firstly, rise in GDP (or GDP per capita) is found to have a positive link with automobile industry's development by increasing consumption through the rise of disposable income. This in turn causes automobile sales to rise and triggers increase in production. On the contrary, an increase in inflation has a negative impact on sales through the reduction in real purchasing power of economic agents.

Unemployment rate is also found to have a negative correlation with demand for automobiles, since a smaller part of working-age population can afford the purchase of durable goods.

The same negative correlation is found for petroleum prices and interest rates. In the first case, an increase in crude oil price reduces both production and demand, because of a relatively higher price that shrinks budget constraints for firms and households. In the latter, a less accommodating monetary policy determines a reduction in loans conditions for purchase of durable goods by consumers and postponements in investments decisions by automakers.

As regards exchange currency rate, a relatively stronger domestic currency raises domestic demand through cheaper imports. Conversely, a domestic currency depreciation increases exports but lowers automobile domestic demand.

Literature research clarifies which are the most important macroeconomic variables that deeply affect automobile market structure. The purpose of this thesis is investigating both the long-term and the short-term relationship between the selected macroeconomic variables – inflation rate, GDP per capita, oil price and interest rate – and passenger car sales within the EU automobile markets. The analysis covers both the aggregate European market data and the specific country-level figures. In this latter case, the aim is to verify empirically the dynamics discussed in Chapter 1. Specifically, it is possible that some countries suffered mostly from the outbreak of recent financial crisis because of the strong linkage with their structural macroeconomic conditions. However, there could be some evidence of some differences in the responsiveness of the automobile market to the impulses coming from the monetary policies.

# 3. A model for the European automobile market

## 3.1 Description of data

For this research, the time series of annual data from 1990 to 2015 of quantity of automobiles sold and four macroeconomic indicators are used. This period was chosen both for the availability of data and, more importantly, to evaluate the impact of recent financial crisis, especially for the country-specific analysis.
Here is a detailed description of the selected data.

- ***Car_reg***. Data on quantity of automobiles sold within the European market are from *ACEA* (*European Automobile Manufacturers' Association*). These quantity data express new passenger cars registrations for Western Europe countries. For this purpose, we consider the aggregation of EU-15 and EFTA countries[3].
- ***infl_rate***. Data on inflation rate for Eurooe are taken from Eurostat Database. Data for single countries are taken from World Bank Database. It is calculated as the consumer price index which reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or changed at specified intervals, such as yearly. The figures are expressed as a % annual change.
- ***GDPPercapita***. Data on GDP per capita are from Eurostat Database and are measured in euros at market prices per capita.
- ***oil_price***. Data on oil prices series are from Eurostat and represent the average price of Brent crude oil 1 month-forward free on board (€/barrel).
- ***int_rate***. Interest rate for the analysis on European aggregate data is expressed as the money market interest rate (EONIA Overnight rate) and data are taken from ECB Database. However, data on interest rate are different for what concerns the more specific country-level analysis. Data on interest rate for individual countries are taken from OECD Database and express the short-term three month interest rate.

All calculations are performed through the software of *Gretl*.

[3] EU-15 countries are the Member States before the 2004 enlargement (BE, DK, DE, EL, ES, FR, IE, IT, LU, NL, AT, PT, FI, SE, UK). EFTA countries include Iceland, Norway and Switzerland.

### 3.2 Model framework

By following Muhammad et al. (2013), in the long-term annual passenger car sales depend on Harmonised Index of Consumer Prices (HICP), Index of Industrial Production (IPP), Oil Price (OIL) and interest rate of loans offered by banking institutions (ONR).
However, on the basis of some preliminary simulations that are reported in paragraph 5.1 – which investigate the stationarity of the selected variables and their order of integration – this thesis considers slightly different adaptations for the considered macroeconomic variables.
On one hand, the HICP Index is substituted by the inflation rate itself. This indicator, expressed as an annual rate of change, is easier to interpret in the VAR specification.
On the other hand, Index of Industrial Production is substituted by GDP per capita variable, which allows to take into account the heterogeneity of income distribution throughout the European economies. This choice is in line with Haugh et al. considerations (2010), too.
Equation (2) reports the main relationship object of investigation.

$$Car\_reg = f(\inf\_rate, GDPPercapita, oil\_price, \text{int}\_rate) \tag{2}$$

Then, the proper logarithmic transformation is applied to variables that are measured in the form of monetary amounts. This method is in line with the work by Haugh et al. (2012), in which only *Car_reg*, *GDPPercapita* and *oil_price* variables are computed in the logarithmic form. As a matter of fact, the variables *infl_rate* and *int_rate* can usually report negative values, like periods of deflation or negative values of interest rates, which would be lost with the logarithmic transformation.
Equation (3) reports eq. (2) with the proper logarithmic transformations.

$$LNcar_t = \beta_1 \inf_t + \beta_2 LNgdppc_t + \beta_3 LNoil_t + \beta_4 \text{int}_t + \varepsilon_t \tag{3}$$

In this way, coefficients $\beta_2$ and $\beta_3$ can be interpreted as estimated elasticities. For instance, $\beta_2$ estimates the percentage change of car sales change given a 1% increase in the GDP per capita. On the other hand, $\beta_3$ represents the estimated percentage change of car sales given a 1% increase in the oil price.

Table 8 reports the results of a simple OLS estimation.

**Table 8: OLS Model for car registrations**

| Regressors | Dependent variable (l_Car_reg) |
|---|---|
| const | 7,58421<br>(2,57005)*** |
| infl_rate | 0,484385<br>(2,52049) |
| l_GDPPercapita | 0,934796<br>(0,272846)*** |
| l_oil_price | −0,213958<br>(0,0763727)** |
| int_rate | 2,84884<br>(1,94426) |
| Observations | T = 21 |
| SER | 0,063375 |
| R-square adjusted | 0,431376 |
| F(4, 16) | 4,793150 |

Hereafter, coefficients are statistically significant at 10%*, 5%** and 1%*** levels. Standard errors in brackets.

Table 8 reports that the rise in the inflation rate seems to increase car registrations. However, the coefficient does not show any statistical significance (p-value = 85%). As regards GDP per capita, the model reports a significant positive correlation with car registrations at 1% reliability level, confirming the role that automobile market has on the whole economy and on business cycles. Moreover, sign of oil price coefficient is also in line with expectations since a rise in the oil price tends to increase production costs for automobile producers who are forced to reduce output in order to respect their budget constraints. The estimation for this parameter is statistically significant at 5%. Surprisingly, the coefficient of interest rate reports a positive value. However, its estimation does not show any statistical significance.

In the second stage of the analysis, the VAR representation of the above equation is provided. This step is carried out in order to analyse both the long-term and the short-term causal relationship among variables of interest.

Therefore, the model of the previous equation can be written as in eq. (4).

$$\begin{bmatrix} car\_reg \\ \text{infl}\_rate \\ GDPPC \\ Oil\_price \\ \text{int}\_rate \end{bmatrix} = \begin{bmatrix} \beta_{01} \\ \beta_{02} \\ \beta_{03} \\ \beta_{04} \\ \beta_{05} \end{bmatrix} + \begin{bmatrix} \beta_{11} & \beta_{12} & \beta_{13} & \beta_{14} & \beta_{15} \\ \beta_{21} & \beta_{22} & \beta_{23} & \beta_{24} & \beta_{25} \\ \beta_{31} & \beta_{32} & \beta_{33} & \beta_{34} & \beta_{35} \\ \beta_{41} & \beta_{42} & \beta_{43} & \beta_{44} & \beta_{45} \\ \beta_{51} & \beta_{52} & \beta_{53} & \beta_{54} & \beta_{55} \end{bmatrix} \begin{bmatrix} car\_reg_{t-1} \\ \text{infl}\_rate_{t-1} \\ GDPPC_{t-1} \\ Oil\_price_{t-1} \\ \text{int}\_rate_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{t1} \\ \varepsilon_{t2} \\ \varepsilon_{t3} \\ \varepsilon_{t4} \\ \varepsilon_{t5} \end{bmatrix} \tag{4}$$

The VAR specification in eq. (4) represents the dynamic model for the European automobile market. The dimension of the VAR is equal to 5 (k = 5), which is the number of equations that have to be estimated. The number of lags is equal to 1 (p = 1)[4], while $\varepsilon_t$ represents the Gaussian innovations distributed with zero mean and variance Σ. As a whole, the number of parameters to estimate is given by $k+k^2+k=k(k+2) = 35$. The estimation of the parameters allows to draw conclusions about AR-direct effect (parameter of l_car_reg itself) and the other cross-effects given by the impact of macroeconomic variables over car registrations.
Eq. (5) represents the VAR model in a compact matricial form.

$$y_t = \beta + A(L) * y_{t-1} + \varepsilon_t \tag{5}$$

Long-run multipliers are included in the A(L) matrix of coefficients. The expectations for their signs are different according to the equation under object of inference. Specifically, $\beta_{13}$ should be higher than zero given the expected positive relationship between disposable income and the levels of car registrations. On the contrary, the other coefficients $\beta_{12}$, $\beta_{14}$ and $\beta_{15}$ should be negative.

[4] The VAR(1) represented in equations (4) and (5) assumes only one lag (p=1). This is only a simplification aimed at a better intuition. However, the exact number of lags of the model is investigated in Chapter 5.

# 4. Research methodology

In this thesis, the standard approach of time series analysis is adopted. The roadmap is based on the one suggested by the paper of Muhammad et al. (2013), which moves from the basic tests for detecting the degree of integration of each of the selected variables to the final determination of the correct model. This procedure enables to draw conclusions about long-term and short-term relationship among the four macroeconomic variables and the evolution of the European automobile market, both from an aggregate and from a country-level perspective. Moreover, the estimations allow to depict the exact direction of causality that has affected the European economy during the last 25 years.

The introductory informal analysis based on correlation matrix and plots is object of paragraphs 4.1 and 4.2. Chapter 5 puts these intuitions into formal way, by following the standard procedure for the aggregate European context. Chapter 6 follows the same approach for the country-level analysis.

The first step is to study each time series variable with the use of the Augmented Dickey-Fuller (ADF), the ADF-GLS and the Kwiatkowsky, Phillips, Schmidt e Shin (KPSS) tests. Beyond the simple detection of a unit root, this step is necessary in order to establish whether the variables have the same degree of integration or not. This last investigation affects the choice of the model that will fit data best. Moreover, a first look at the plots and the unit root tests enables to make some hypothesis about the possibility of co-movements among the variables. As a hint, two or more variables with the same degree of integration might be co-integrated and follow a long-run relationship, based on some equilibrium linkage.

The second step is about the determination of the proper lag to include in the VAR (or VECM) model discussed in the previous chapter. For this purpose, the traditional information criteria are used.

Then, some of the main diagnostic tests are performed in order to verify the validity of the resulting estimators. The aim is to confirm that data are independently and normally distributed. This condition allows to obtain consistent estimators and make valid inference.

The third step deals with the cointegration analysis, based on Engle and Granger approach. Then, on the basis of the Johansen's approach, the determination of the exact number of co-integration relationships is undertaken. For this investigation, the trace test for co-integration based on eigenvalues is performed.

Eventually, the Vector Error Correction Model (VECM) is specified, with the main aim of discriminating between endogenous and exogenous variables. This method includes an error correction term (or disequilibrium) which takes into account the speed of adjustment of a variable in the long-run. Causal short-term considerations are derived from VECM, too.

## 4.1 Correlation matrix and test for normality

The introductory analysis begins with the analysis of the correlation matrix, reported in Table 9 below.

**Table 9: Correlation matrix analysis**

| | **New automobile registrations** | Inflation Rate | GDP per capita | Oil Price | Interest rate |
|---|---|---|---|---|---|
| **New automobile registrations** | **1** | | | | |
| Inflation Rate | **0,1120** | 1 | | | |
| GDP per capita | **-0,1982** | -0,4295 | 1 | | |
| Oil Price | **-0,5150** | -0,1903 | 0,8630 | 1 | |
| Interest rate | **0,3886** | 0,7191 | -0,7803 | -0,7172 | 1 |

On the basis of the results in Table 9, oil price is negatively correlated with the new automobile registrations. This conclusion is in line with the theoretical framework. The positive correlation between the interest rate and the new automobile registrations contradicts the theoretical framework because higher levels of interest rates within the economic system should lower the aggregate demand for new cars. A possible explanation could lie in the presence of some frictions within channels of transmission of monetary policy through the actors of automobile market. As regards GDP per capita, Table 9 reports a negative value, which does not fit with the results of the OLS estimation reported in Table 8. However, this last result might be due to the strong impact of recent financial crisis. Lastly, the positive correlation between the inflation rate and the new automobile registrations is not in line with the theoretical framework.

The Jarque-Bera-Lomnicky Test for nonormality is performed, too. This test is based on the calculation of third and fourth moments of a distribution. Under the null hypothesis, the degree of skewness and excess kurtosis are simultaneously equal to zero. The test statistic is called JB statistic and follows $X^2$ distribution with two degrees of freedom. Therefore, the null hypothesis of normal distribution is rejected for too high values of JB test statistic.
Table 10 shows that all selected variables follow normal distributions.

**Table 10: Jarque-Bera Test for Nonnormality**

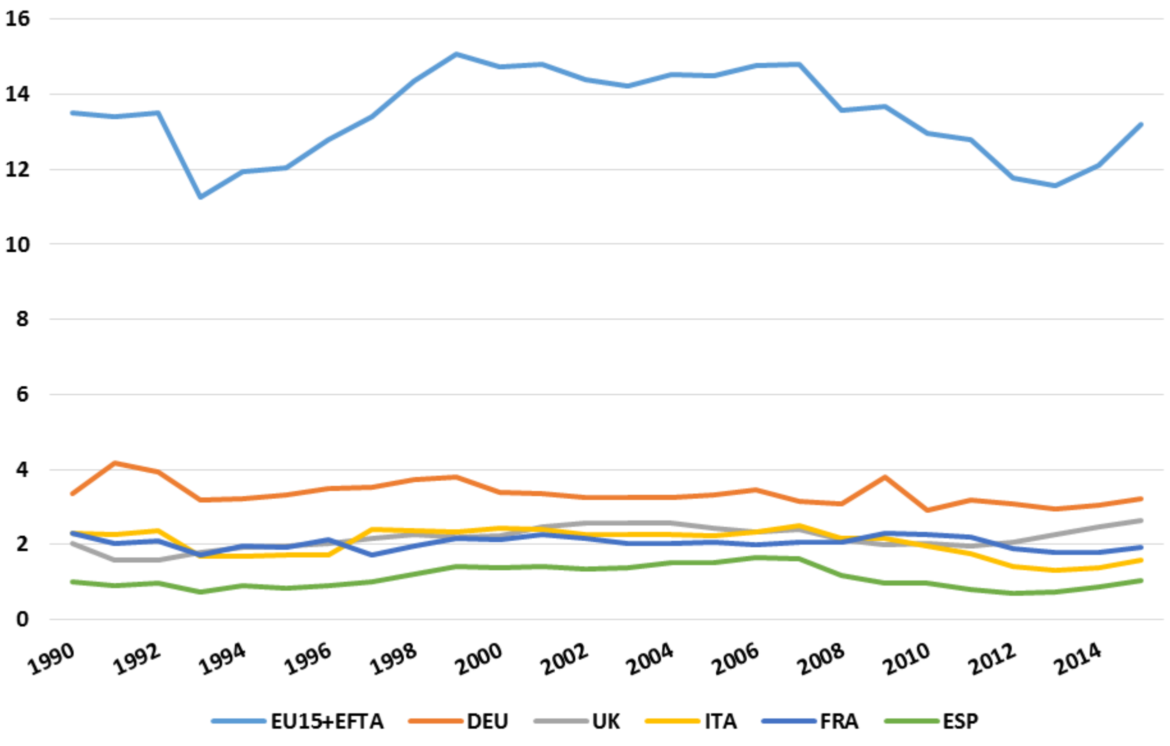
| Variable | JB Statistic Test | p-value |
|---|---|---|
| l_Car_reg | 1,91439 | 0,383968 |
| Infl_rate | 0,917527 | 0,632065 |
| l_GDPPercapita | 2,04892 | 0,358989 |
| l_Oil_price | 2,33679 | 0,310865 |
| Int_rate | 0,989312 | 0,609781 |

## 4.2 Informal analysis

In this section, an informal analysis based on the observation of time series plots is conducted. Plotting the variables against time enables to highlight some patterns and make first considerations about stationarity. Basically, a time series may be the result of some random stochastic shocks or might exhibit a pattern moving around a trend, which is a persistence in the long-term. This latter case is frequent for economic variables.

Figure 11 displays the quantities of automobile registrations in Europe and in every single selected country during the period 1990-2015. The plot clearly shows that the variable *Car_reg* contains a unit root and needs to be differentiated once to reach stationarity.

**Figure 11: Car registrations in millions in Europe**

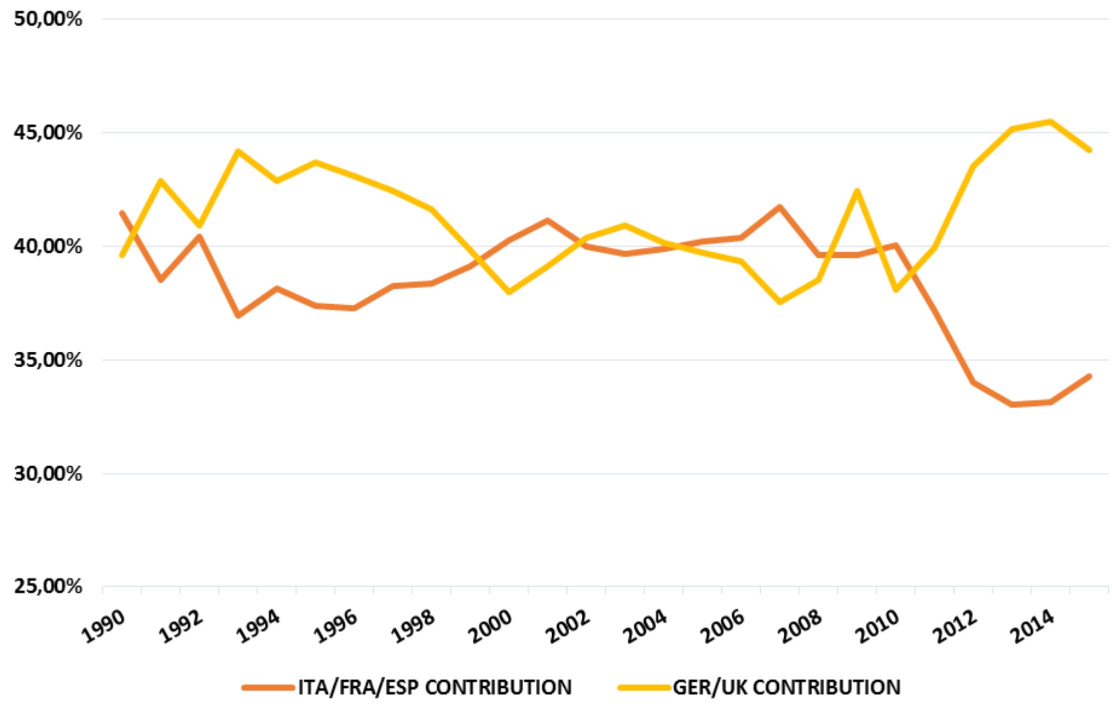



*Source:* Author's own elaboration. Data from ACEA database.

By having a look at Figure 11 related to European aggregate car registrations, one can identify three main periods. The first sub-period refers to a constant up-ward evolution which has a peak in 1999, when 15066357 cars were registered in the EU-15 countries. The second sub-period lasts until 2007, when the second most relevant peak occurs (14793643 registered cars). The turning point is represented by the outbreak of financial crisis in 2007/08, followed by persistent drops in all car registrations figures, especially for Italy, France and Spain. As regards the most recent times, one can state that recovery is different across countries. On one hand, Germany and UK reached their worst moment in 2010 and 2011, respectively. On the other hand, Italy, France and Spain reached their trough in 2013, confirming a slower recovery which affects the whole European automobile market.

The analysis of Figure 12 is straightforward. The plot displays the percentages of the two groups of countries under investigation as a ratio over the total European car registrations. The plot shows that the weak contribution by Italy, France and Spain is only limited to the most recent period. As reported by Lee-Makiyama (2012), these countries were hit the most by the recent financial crisis because of three main reasons. First, the outbreak of the financial crisis and the second industrial crisis in 2010 reveal the presence of deeply rooted structural problems and saturated demand. Overcapacities and low propensity to consumption led to even lower levels of sales. Second, there is a progressive decline in innovation and productivity, which contribute to the creation of a disequilibrium between the amount of R&D spending and value-added. Third, there is an unbalanced relationship between the amount of exports and imports to Europe. Comparative advantages led to deep specialization for the production of premium and large-sized cars, which in turn led to a large trade surplus. However, there is a small level of competition with respect to imported cars whose market-share is too low to stimulate improvement in the small-sized cars' production.

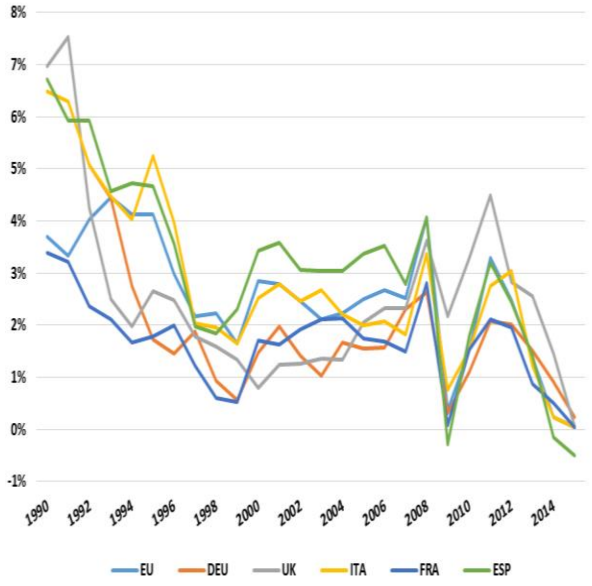
**Figure 12: Percentages of car registrations over the total in Europe**



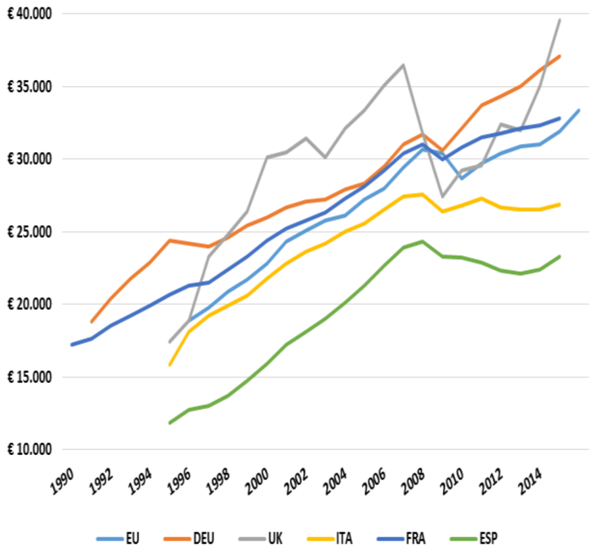

*Source:* Author's own elaboration. Data from ACEA database.

Figure 13 displays the four selected macroeconomic variables' plots.

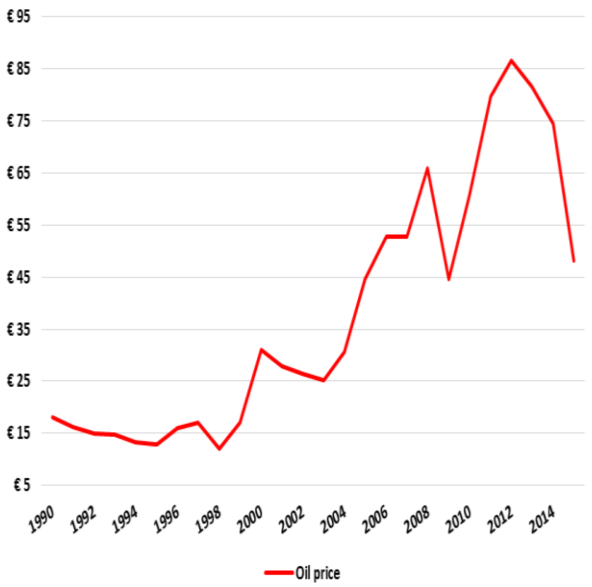
**Figure 13: Inflation Rate (a), GDP at current prices in euro per capita (b), Brent crude oil 1-month Forward euro per barrel (c) and interest rates (d)**



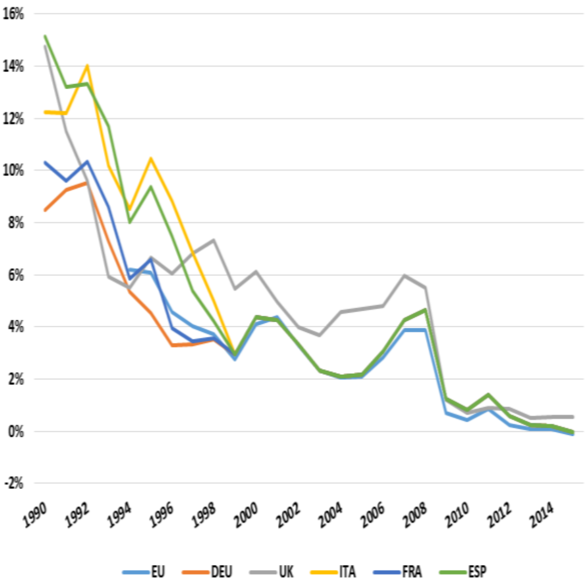

Inflation rate (a)




GDP per capita (b)




Oil price (c)



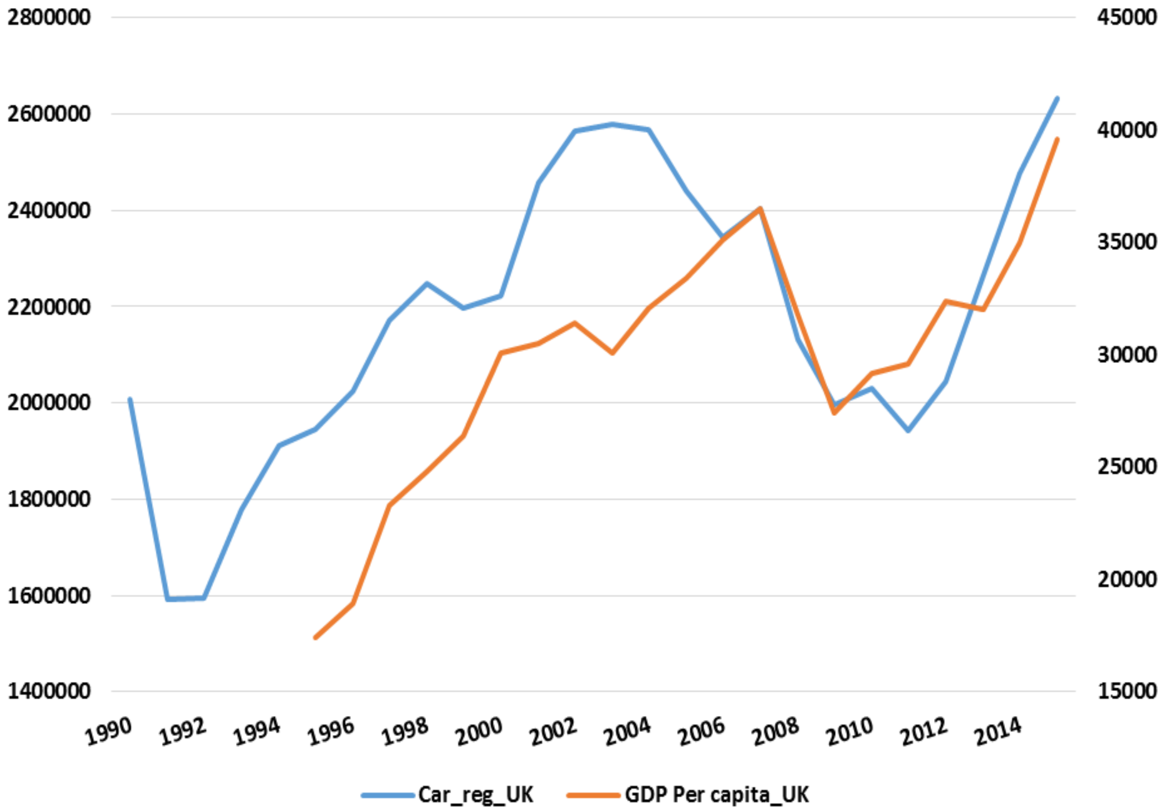

Interest rate (d)

*Source:* Author's own elaboration. Data from Eurostat database.

As shown in Figure 13, all the macroeconomic variables follow stochastic random walks and need to be differentiated at least once to reach stationarity.

An interesting relationship occurs in plotting Figure 14, which displays the amount of car registrations on the left vertical axis and levels of GDP per capita on the right vertical axis for data on UK. The variables show some evidence of co-movement, especially for those periods from 1995 to 2000 and from 2007 to 2010.

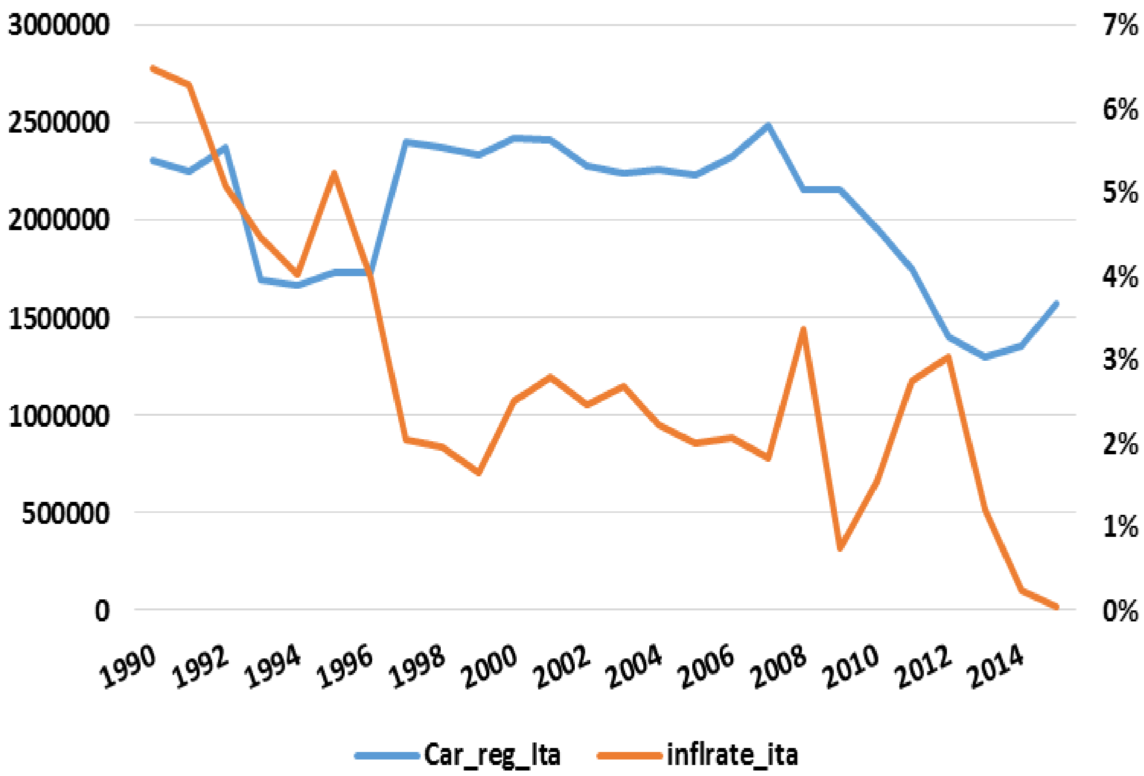
**Figure 14: Car registrations and GDP per capita in UK**




*Source:* Author’s own elaboration. Data from ACEA and Eurostat database.

A further plot is reported in Figure 15, which shows the levels of car registrations on the left vertical axis and the inflation rate on the right one for data on Italy. The two variables seem to move together especially in the period from 1997 to 2007. Afterwards, the relationship turns to be ambiguous for the period after the outbreak of the financial crisis in 2008.

**Figure 15: Car registrations and inflation rate in Italy**




*Source:* Author’s own elaboration. Data from ACEA and Eurostat database.

# 5. Empirical results

This Chapter moves along the standard approach of time series analysis discussing the results related to the aggregate European automobile market. After a preliminary overview of the main stationarity tests, the procedure goes on with the selection of proper lags for VAR model, the cointegration analysis and the final model implementation. Moreover, paragraphs 5.7 and 5.8 suggest Impulse-Response and Forecast Error Variance Decomposition analysis in order to detect the magnitude of macroeconomic shocks over the European car market.
This step-procedure is repeated in the last paragraph, adapting it for single countries.

## 5.1 Unit root tests

This section investigates the degree of integration of our selected variables in order to discriminate between stationary and non-stationary variables. On one hand, this step is essential for preventing the case of spurious regression, which occurs when two or more variables are generated by independent random walks and following some kind of linear trends. On the other hand, two or more variables could share a common stochastic trend, which determines a long-term relationship based on an error correction model. This last case is directly linked with cointegration analysis, which is performed in paragraph 5.4.
In this section, only unit root test for each single selected variable is performed.
Hereafter the case of random walk (RW) process with trend is considered. This process exhibits a unit root.

$$
\begin{aligned}
&Y_t = \delta + Y_{t-1} + u_t = Y_0 + \delta t + \sum_{i=1}^{t} u_i \\
&E(Y_t) = Y_0 + \delta t \\
&Var(Y_t) = \sigma^2 t \\
&\rho_{k,t} = Corr(Y_t, Y_{t-k}) = \sqrt{1 - \frac{k}{t}}
\end{aligned}
\qquad (6)
$$

As shown in Equation (6), the expectation of the variable $Y_t$ is dependent on time t. Additionally, the variance of $Y_t$ increases with time. Moreover, the last formula states that if value of k increases, the correlation between $Y_t$ and its k-th lag increases, too. Therefore, RW

process is not stationary and exhibits unit root. In a way, the process has a long memory and each value of the variable is affected by the previous realizations of the variable itself.
The instrument used to detect the presence of a unit root is the Augmented Dickey-Fuller (ADF) test. A random walk is a special case of AR(1)[5] with $\beta_1$=1. Therefore, the test hypothesis is represented as in equation (7).

$$\begin{cases} H_0 : \beta_1 = 1 \\ H_1 : \beta_1 < 1 \end{cases} \tag{7}$$

Under the null hypothesis, the process has a unit root. Under the alternative unilateral hypothesis, the process is stationary. However, the test is usually carried on by the following test hypothesis[6].

$$\begin{cases} H_0 : \delta = 0 \\ H_1 : \delta < 0 \end{cases} \tag{8}$$

Where $\delta = \beta_1$-1. Since the ADF statistics is not normally distributed, its value is compared with special critical values, which depend on the choice of the inclusion of a deterministic trend in the alternative hypothesis.
The additional test statistic to consider is the KPSS Test Statistic, whose null hypothesis is contrary to the one stated in the Augmented Dickey-Fuller test. This means that under the null hypothesis, the variable has no unit root.
Table 11, 12 and 13 report the ADF, ADF-GLS and KPSS Test for the selected variables with the value of the test statistic and the correspondent p-value. The correct number of lags has been selected by looking at correlograms and Partial Autocorrelation Functions (PACF) for each single variable. Moreover, by following Sjö (2008), all tests are firstly modelled with a less restricting representation, including a constant and a trend. Thus, in case of evidence of a unit root, a more efficient model without a time trend is evaluated.

[5] An AR (1) process is given by the following equation, in which the value of a variable is simply function of its first lag: $Y_t = \beta_0 + \beta_1 Y_{t-1} + u_t$.
[6] By subtracting $Y_{t-1}$ from both sides of $Y_t = \beta_0 + \beta_1 Y_{t-1} + u_t$ we obtain $\Delta Y_t = \beta_0 + \delta Y_{t-1} + u_t$. This equation at first differences is commonly used by econometric softwares.

**Table 11: ADF unit root test analysis**

| Variable | Levels | First Difference | Second Difference |
|---|---|---|---|
| | ADF Test (p-value) | ADF Test (p-value) | ADF Test (p-value) |
| l_Car_reg | -2,35004 (0,4061) | -4,17838 (0,01582) | |
| Infl_rate | -3,50584 (0,06049) | -4,87721 (0,000311) | |
| l_Gdppc | -1,8632 (0,6355) | -2,93846 (0,05949) | -4,87948 (0,005659) |
| l_Oil_price | -2,53848 (0,3086) | -4,04899 (0,02073) | |
| Int_rate | -2,80335 (0,2112) | -3,95776 (0,02855) | |

**Table 12: ADF-GLS unit root test analysis**

| Variable | Levels | First Difference | Second Difference |
|---|---|---|---|
| | ADF-GLS Test | ADF-GLS Test | ADF-GLS Test |
| l_Car_reg | -1,6766 | -4,39124 | |
| Infl_rate | -2,09065 | -6,30513 | |
| l_Gdppc | -0,184343 | -2,92518 | -5,03372 |
| l_Oil_price | -0,828184 | -3,93506 | |
| Int_rate | -1,04416 | -4,13305 | |

where critical values for ADF-GLS statistics at 10, 5, 2,5 and 1% are respectively -2,89, -3,19, -3,46 and -3,77

**Table 13: KPSS unit root test analysis**

| Variable | Levels | First Difference | Second Difference |
|---|---|---|---|
| | KPSS Test (p-value) | KPSS Test (p-value) | KPSS Test (p-value) |
| l_Car_reg | 0,236856 (< .01) | 0,0922769 (> .10) | |
| Infl_rate | 0,787807 (< .01) | 0,0470754 (> .10) | |
| l_Gdppc | 0,254578 (< .01) | 0,0929132 (> .10) | |
| l_Oil_price | 0,12781 (0,091) | 0,117334 (> .10) | |
| Int_rate | 0,9801 (< .01) | 0,0523736 (> .10) | |

Results on unit root tests confirm that all selected variables are non-stationary. All variables are integrated of order one I(1), except for *l_Gdppc*, which needs to be differentiated twice to get stationarity. Therefore, the first difference of *l_Gdppc* will be used in the VAR model.

### 5.2 Lags selection

This section aims to detect the correct number of lags to be included in the model. The choice should be motivated by econometric tests for residuals autocorrelation but also from economic intuition and experience. Generally, 1 or 2 should be the correct number of lags to select in the case of annual data.

Table 14 reports the results for the choice of lags. The Akaike Information Criterion (AIC) and the Hannan-Quinn Criterion (HQC) criteria suggest to choose lag 2 while Bayesian Information Criterion (BIC) informs about 1 lag. In this thesis, lag 2 is chosen for implementing the correct VAR specification, the trace test for cointegration and the implementation of the proper model.

**Table 14: Selection of lags**

| Lag | logver | p(LR) | AIC | BIC | HQC |
|---|---|---|---|---|---|
| 1 | 252,68128 | | -24,742365 | -23,258412* | -24,537748 |
| 2 | 288,06615 | 0 | -25,896238* | -23,175658 | -25,521107* |

## 5.3 VAR estimation and diagnostic tests

The following step is to implement a preliminary VAR model, on the basis of the chosen number of lags (p=2).

Table 15 reports the VAR estimation for l_Car_reg.

**Table 15: VAR model for car registrations**

| Regressors | Dependent variable (l_Car_reg) |
|---|---|
| const | 9,57195<br>(4,72037)* |
| l_Car_reg_1 | 0,593452<br>(0,574069) |
| l_Car_reg_2 | −0,158051<br>(0,63003) |
| infl_rate_1 | −2,16388<br>(3,04876) |
| infl_rate_2 | 0,113972<br>(3,70437) |
| d_l_GDPPercapita_1 | −0,698509<br>(1,2492) |
| d_l_GDPPercapita_2 | −0,214542<br>(1,19772) |
| l_oil_price_1 | −0,0138699<br>(0,0977575) |
| l_oil_price_2 | −0,0546631<br>(0,0863898) |
| int_rate_1 | 4,06326<br>(4,36749) |
| int_rate_2 | −2,74263<br>(5,13931) |
| Observations | T = 18 |
| SER | 0,049775 |
| R-square adjusted | 0,652096 |
| F(10, 7) | 4,186408 |

The first diagnostic test presented in Table 16 shows that we can't reject the null hypothesis of no autocorrelation in each of the equations. This means that data are independently distributed.

**Table 16: LM Test for Residual Autocorrelation for VAR**

Equation 1

Ljung-Box Q' = 0,0637007 with p-value = P(Chi-square(1) > 0,0637007) = 0,801

Equation 2

Ljung-Box Q' = 2,46738 with p-value = P(Chi-square(1) > 2,46738) = 0,116

Equation 3

Ljung-Box Q' = 0,520964 with p-value = P(Chi-square(1) > 0,520964) = 0,47

Equation 4

Ljung-Box Q' = 0,00403022 with p-value = P(Chi- square(1) > 0,00403022) = 0,949

Equation 5

Ljung-Box Q' = 0,922377 with p-value = P(Chi- square(1) > 0,922377) = 0,337

Table 17 reports the ARCH test for conditional heteroskedasticity. Under the null hypothesis, there's no ARCH effect and this condition assures conditional homoskedasticity for valid inference.

**Table 17: Test for conditional homoscedasticity**

Equation 1

Test Statistic: LM = 0,304619 with p-value = P(Chi-square(1) > 0,304619) = 0,581001

Equation 2

Test Statistic: LM = 1,25991 with p-value = P(Chi-square(1) > 1,25991) = 0,261668

Equation 3

Test Statistic: LM = 0,36306 with p-value = P(Chi-square(1) > 0,36306) = 0,546812

Equation 4

Test Statistic: LM = 0,00930728 with p-value = P(Chi-square(1) > 0,00930728) = 0,923144

Equation 5

Test Statistic: LM = 0,178305 with p-value = P(Chi-square(1) > 0,178305) = 0,672834

The last test is about normality of the residuals from the equations obtained with VAR. Under the null hypothesis, the residuals are normally distributed and there are no significant outliers. Table 18 reports the results for normality of residuals. The null hypothesis is accepted at the 1% reliability level.

**Table 18: Test for normality of residuals**

| |
|---|
| Doornik-Hansen Test |
| Chi-square(10) = 18,5058 [with p-value = 0,0470] |

## 5.4 Cointegration Analysis

On the basis of the results reported in paragraphs 5.1 and 5.2, this section proceeds with the cointegration analysis.

Given that all the selected variables have the same degree of integration I(1), the point is now to discriminate between independent random walks and possibilities of long run co-movements among the selected variables. In the latter case, cointegration concept is implied. Cointegration is defined as the co-movement of two (or more) time series in the long-run. In the simplest case of two variables, the long-run equilibrium relationship is embodied in some value $\beta$ such that $y_t - \beta x_t$ is integrated of order 0, or I(0), while $y_t$ and $x_t$ are I(1) processes. Thus, there exists a parameter $\beta$ which allows to eliminate the stochastic trend component shared by the two considered variables.

The approach suggested by Engle-Granger (1987) allows to verify that there exists at least one cointegration relationship. This test is based on the following roadmap, when the parameter $\beta$ is unknown:

1) Determine the degree of integration for all variables;
2) Estimate the cointegrating regression with OLS approach;
3) Determine whether the residuals of the regression in step 2 are stationary or not. In particular:
    a) $H_0$: unit root (no cointegration);
    b) $H_1$: no unit root (cointegration).

On the basis of available data, the Engle-Granger cointegration test for the five considered variables is implemented.

Table 19 reports the test result analysis, based on the number of lags found in paragraph 5.2. The p-value for the residuals' regression shows that the four macroeconomic variables do not cointegrate with car sales. Since the unit root null hypothesis for the residuals is not rejected even at the 10% reliability level (p-value=0,8713), the residuals are I(1).

**Table 19: Two steps Engle-Granger cointegration test**

| Regressors | Dependent variable (l_Car_reg) |
|---|---|
| Constant | 16,4210 (0,172235) |
| infl_rate | −1,55732 (2,52324) |
| d_l_GDPPercapita | 0,122963 (0,634831) |
| l_oil_price | −0,0111015 (0,0437912) |
| int_rate | 3,42133 (2,09259) |
| Observations | T = 20 |
| SER | 0,068088 |
| R-square adjusted | 0,300704 |
| Test for unit root in the residuals of the regression above | |
| Test Statistic tau_c(5) = -2,33014 | |
| p-value = 0,8713 | |

Nonetheless, a more practical approach suggested by Sjö (2008) allows to test cointegration in a single error correction model for the dependent variable object of interest. The idea is to estimate an error correction model and then include it in an equation of variables in first differences. In such a model, the error correction model is the only potential I(1) variable. Table 20 reports the results of this single error correction model.

**Table 20: Pragmatic Single Error Correction Model for car registrations**

| Regressors | Dependent variable (d_l_Car_reg) |
|---|---|
| d_infl_rate_1 | 0,401795 (1,44177) |
| d_d_l_GDPPercapita_1 | 0,104165 (0,351614) |
| d_l_oil_price_1 | 0,0347568 (0,0531178) |
| d_int_rate_1 | −0,812738 (1,57939) |
| uhat11_1 | −0,55766 (0,210598)** |
| d_l_Car_reg_1 | 0,506206 (0,282312)* |
| Observations | T = 18 |
| SER | 0,041220 |
| R-square adjusted | 0,214787 |
| F(6, 12) | 1,608364 |

Table 20 shows that the coefficient for *uhat11_1* is statistically significant at the 5% reliability level. This result seems to justify a co-movement of macroeconomic variables in order to restore the long-run equilibrium for car registrations in Europe.

The second stage of the cointegration analysis is to detect the exact number of cointegration relations among the selected variables, through the method introduced by Johansen (1988). This technique is called trace test for cointegration and is considered the most robust test, as suggested by Sjö (2008).

Before moving to the description and the implementation of the test, a theoretical framework is provided. The starting point is to recall the definition of a general VAR(p) process, formalized in equation (9).

$$y_t = A_1 y_{t-1} + \ldots + A_p y_{t-p} + u_t \tag{9}$$

Where $A_i$ are K*K matrices and innovations are white noise $u_t \sim (0,\Sigma)$. By subtracting $y_{t-1}$ from both sides of equation (9), the Vector Error Correction Model in eq. (10) is derived.

$$\begin{aligned} \Delta y_t &= \Pi y_{t-1} + \Gamma_1 \Delta y_{t-1} + \ldots + \Gamma_{p-1} \Delta y_{t-p+1} + u_t \\ \Delta y_t &= \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + u_t \end{aligned} \tag{10}$$

Where equation (11) specifies the composition of the coefficients' matrices.

$$\begin{aligned} \Pi &= -(I_k - A_1 - \ldots - A_p) \\ \Gamma_i &= -(A_{i+1} + \ldots + A_p) \end{aligned} \tag{11}$$

The VECM representation allows to integrate both long-run and short-run dynamics. On one hand, the matrices $\Gamma_i$s correspond to the short-run dynamic adjustment mechanism. On the other hand, $\Pi y_{t-1}$ accounts for the long-run component since it represents the error correction terms. In particular, each correction term is made up by two parts: one is the deviation of a variable from its long-run equilibrium and the other one is the speed of adjustment to this long-run equilibrium. This intuition will be empirically investigated in the next paragraph.

For the purpose of this section, the properties of the matrix $\Pi$ are taken into account. As a matter of fact, the cointegration analysis is based on the rank of $\Pi$ which measures the maximum number of linearly independent vectors and therefore it provides the maximum number of cointegration relations. The rank of Π is crucial for the cointegration analysis, because there is only one case in which the inclusion of an error correction term is justified. The three possible cases are here listed.

1. If r = rank(Π) = 0 there is no cointegration at all. All variables are I(1) but do not co-move. First differences are stationary, so a VAR for $\Delta y_t$ is the correct model to implement;
2. If r = rank(Π) = k there is full rank. All variables are already stationary I(0). Hence, a VAR for $y_t$ in levels is the proper solution;
3. If 0 < rank(Π)=r < k there are r cointegration relationships. Only in this case, the matrix Π can be written as $\alpha\beta'$, where $\beta'$ is the cointegration vector and α is the response or speed of adjustment from equilibrium in the previous period.

According to Johansen's approach, the number of cointegration relations can be traced. Under the null hypothesis, the rank of the matrix is equal to the hypothesized number of cointegration relations, starting from zero. On the contrary, the alternative hypothesis states that the rank of the matrix is higher than the hypothesized number of cointegration relations. In this latter case, an additional hypothesis test should be performed. Equation 12 puts this intuition into formal way.

$$\begin{Bmatrix} H_0 : rang(\Pi) = r_0 \\ H_1 : rang(\Pi) > r_0 \end{Bmatrix} \tag{12}$$

Where $r_0$ goes from 0 to k-1. Basically, this test is based on sequential steps and it ends once the null hypothesis can not be rejected anymore.

Table 21 reports the results for the Johansen trace test for cointegration. The trace test here is adjusted for degrees of freedom, replacing T in the trace statistic by T-nk, as suggested by Reimers (1992).

**Table 21: Johansen trace test for cointegration**

| Rank | Eigenvalue | Trace Test | p-value |
|---|---|---|---|
| 0 | 0,98583 | 106,87 | 0,7152 |
| 1 | 0,85217 | 50,963 | 0,7521 |
| 2 | 0,74470 | 26,35 | 0,5726 |
| 3 | 0,47653 | 9,5743 | 0,5064 |
| 4 | 0,33894 | 0,90465 | 0,4324 |

Results show that there are no cointegration relationships at the 10% reliability level. This conclusion is in line with the Engle and Granger cointegration results reported in Table 19 above. This means that the VAR model should be run in first differences, without the presence of an error correction model.

### 5.5 Phillips' normalization

In the previous paragraph, the main idea of long-term cointegration relationship was introduced. This section focuses on the interpretation of the parameters that belong to the long-run equilibrium equation.

From equation (10), we recall that all the regressors are taken in first differences except for the levels of variables, which enter in t-1 as independent variables. These components refer to the matrix $\Pi y_{t-1}$, which represents the long-term relationship.

The expression can be formalized more clearly with equation (13).

$$\begin{aligned} \Pi y_{t-1} &= \alpha_0 y_{1t-1} + \alpha_1 y_{2t-1} + \alpha_2 y_{3t-1} + \alpha_3 y_{4t-1} + \alpha_4 y_{5t-1} = \\ &= \alpha_0 \left( y_{1t-1} + \frac{\alpha_1}{\alpha_0} y_{2t-1} + \frac{\alpha_2}{\alpha_0} y_{3t-1} + \frac{\alpha_3}{\alpha_0} y_{4t-1} + \frac{\alpha_4}{\alpha_0} y_{5t-1} \right) = \\ &= \alpha_0 \left( y_{1t-1} - \beta_1 y_{2t-1} - \beta_2 y_{3t-1} - \beta_3 y_{4t-1} - \beta_4 y_{5t-1} \right) \end{aligned} \qquad (13)$$

The last row of equation (13) is precisely the error correction term for the dependent variable $y_1$. This term must be included in the model when $0 < r < k$. In particular, the term within brackets is the disequilibrium term of $y_1$ with respect to its long-term equilibrium value.

The parameter $\alpha_0$ represents the speed of adjustment with which $y_1$ in t responds to its disequilibrium in t-1.

By definition, $\alpha_0$ must be negative:

- When the disequilibrium value in brackets in the last row of equation (13) is negative, the mechanism adjustment will increase $y_1$ (disequilibrium<0 and $\alpha_0<0 \rightarrow \Delta y_{1t} >0$) in order to bring it back to its equilibrium value;
- When the disequilibrium value in brackets in the last row of equation (13) is positive, the mechanism adjustment will decrease $y_1$ (disequilibrium>0 and $\alpha_0<0 \rightarrow \Delta y_{1t} <0$) in order to bring it back to its equilibrium value.

In the context of Johansen's test for cointegration, *Gretl* normalizes one coefficient per column to level 1. Therefore, the remaining coefficients can be interpreted as the parameters in the equilibrium relations. The results strongly depend on the assumptions that restrict the analysis to the variables object of interest.

### 5.6 Analysis of VAR in first differences

As reported in paragraph 5.4 in Table 21, the number of cointegration relations is equal to zero. As concerns car registrations, there is no theoretical long-term equilibrium relationship which justifies the inclusion of an error correction term in the model. This is the case in which the term $\Pi y_{t-1}$ is equal to zero and the long-run dynamics disappears, as discussed in the previous paragraph. Therefore, variables are all I(1) and the correct model is a VAR for $\Delta y_t$.
Table 22 reports the VAR model in first differences.

**Table 22: VAR estimation for European automobile registrations**

| Regressors | Dependent variable | | | | |
|---|---|---|---|---|---|
| | Δln(Car_reg) | Δinfl_rate | $\Delta^2$ln(GDPPC) | Δln_oil_price | Δint_rate |
| Δln(Car_reg)_1 | 0,152481<br>(0,409748) | 0,0452367<br>(0,0949325) | 0,404438<br>(0,189687)* | 1,39339<br>(1,96799) | 0,0486838<br>(0,0590081) |
| Δln(Car_reg)_2 | −0,115398<br>(0,592009) | 0,0406367<br>(0,137160) | −0,200045<br>(0,274062) | 0,695412<br>(2,84338) | −0,00914169<br>(0,0852556) |
| Δinfl_rate_1 | −0,432521<br>(2,00066) | −0,726618<br>(0,463522) | −0,440983<br>(0,926175) | −4,2621<br>(9,60903) | −0,700749<br>(0,288116)* |
| Δinfl_rate_2 | −6,95399<br>(2,99051)* | 1,101<br>(0,692856) | 0,156746<br>(1,38441) | 50,4986<br>(14,3632)** | 0,723541<br>(0,430665) |
| $\Delta^2$ln(GDPPC)_1 | 1,1033<br>(1,28527) | −0,0950796<br>(0,297778) | 0,516727<br>(0,594997) | −10,1366<br>(6,17307) | 0,0962012<br>(0,185092) |
| $\Delta^2$ln(GDPPC)_2 | 2,40291<br>(1,17804)* | −0,60158<br>(0,272935)* | 0,0428975<br>(0,545358) | −13,5685<br>(5,65807)* | −0,201605<br>(0,169651) |
| Δln_oil_price_1 | 0,0614271<br>(0,0856865) | −0,00776012<br>(0,0198523) | 0,0325972<br>(0,0396673) | −0,528834<br>(0,411547) | 0,0149918<br>(0,0123398) |
| Δln_oil_price_2 | 0,119581<br>(0,101567) | −0,0238584<br>(0,0235316) | 0,0142451<br>(0,047019) | −1,48191<br>(0,48782)** | −0,0147053<br>(0,0146267) |
| ΔInt_rate_1 | −7,49429<br>(5,28212) | 1,80056<br>(1,22379) | −1,19027<br>(2,44528) | 61,214<br>(25,3697)* | 0,860087<br>(0,760681) |
| ΔInt_rate_2 | 0,845768<br>(2,82267) | −0,467122<br>(0,653970) | −0,85689<br>(1,30671) | −23,4206<br>(13,5571) | −0,527336<br>(0,406495) |
| Observations | T = 18 | T = 18 | T = 18 | T = 18 | T = 18 |
| SER | 0,045689 | 0,010585 | 0,021151 | 0,219441 | 0,006580 |
| R-square adjusted | 0,034911 | 0,257836 | 0,404588 | 0,392113 | 0,558271 |
| F(11, 6) | 1,055904 | 1,536908 | 2,050153 | 1,996883 | 2,953195 |

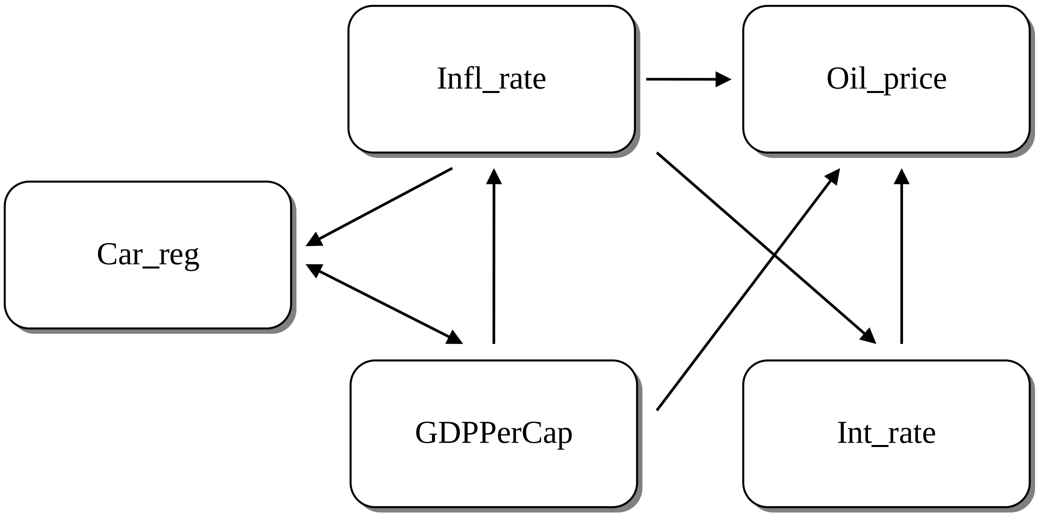
Results show that both changes in inflation rate and GDP per capita are statistically significant in determining the evolution of car registrations in Europe in the short-run. On one hand, the coefficient for inflation rate shows that the increase in level of overall prices diminishes the car purchases in Europe. On the other hand, the level of income per capita positively affects the levels of car sales. In other terms, customers in Europe denote a significant price-sensitivity based on average budget constraints. As regards oil price, no evidence of negative causal relationship is verified, as opposed to the results for the preliminary simple OLS estimation. This result might be due to the diminishing dependence of European automotive industry on the evolution of oil dynamics. The coefficient of the first lag of interest rate is negative, as expected, but is not significant at the 10% reliability level.

Moreover, results confirm that *Car_reg* is an important short-term cause of GDP per capita, showing the two-way positive relationship between the automobile market and business cycles.

As expected, the estimated coefficient of interest rate over GDP per capita is negative. However, t = −1.419 (p-value = 0.2058) showing only some tendency of efficacy of accommodative monetary policy over the consumers' disposable income.

Eventually, interdependence relations in Table 22 are summarized in Figure 16, which shows the complexity of short-term connection between the European automobile market and the macroeconomic environment.

**Figure 16: Granger short-term causal relationship**



### 5.7 Impulse-Response Functions (IRF)

The last two paragraphs of this chapter focus on two econometric techniques that enable to analyse the magnitude of shocks of macroeconomic variables over car registrations.

Both techniques follow from the theorem of Wold's decomposition, which states that if a VAR is stationary, the vector $y_t$ can be expressed as a Vector Moving Average infinite process, or VMA(∞). With the help of maths, eq. (9) can be written as the following eq. (14).

$$y_t = \Phi_0 u_t + \Phi_1 u_{t-1} + \Phi_2 u_{t-2} + \ldots \tag{14}$$

Where $\Phi_0 = I_K$ and $\Phi_s$ is defined as the matrix of marginal effects for s periods ahead. This dynamic effect is expressed in equation (15).

$$\Phi_S = \frac{\delta y_{t+s}}{\delta u_t} \tag{15}$$

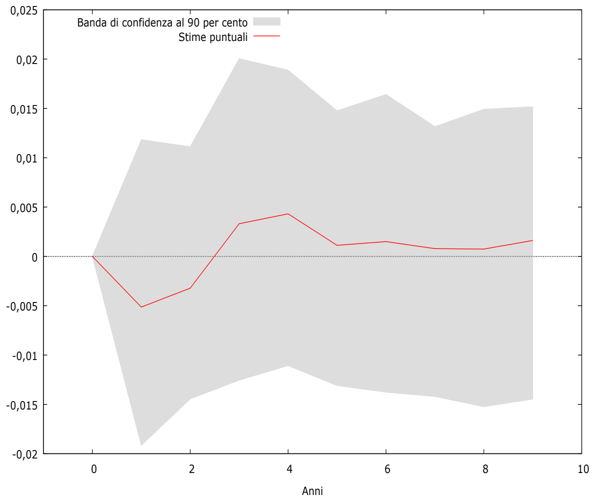
Impulse Response Functions ($IRF_s$) assess the response of the whole VAR (or VECM) system with respect to an exogenous shock, an "impulse" or innovation. $IRF_s$ identify the responsiveness of the dependent (endogenous) variable in the VECM when a shock is put to the error term, holding all other innovations constant. The main idea is to detect for how long and in which way variables in the model dynamically affect each other, given a one standard deviation shock in the error term.

For the purpose of the analysis, $IRF_s$ are generated for 10 periods with Cholesky ordering. $IRF_s$ are plotted within confidence intervals obtained through the bootstrap technique in order to determine whether the marginal effects are statistically significant.

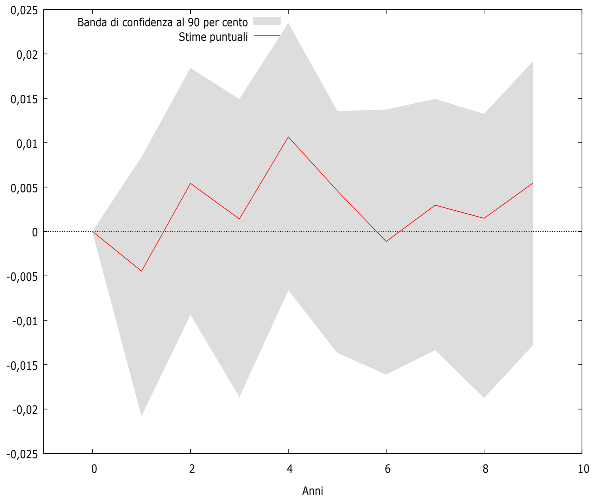
Figure 17, 18 and 19 plot the response of each single variable in the VAR with respect to one standard deviation shock of all the other variables.

**Figure 17: Impulse-response functions of car registrations (a) and inflation rate (b) to one standard-deviation shock to each of the other variables**

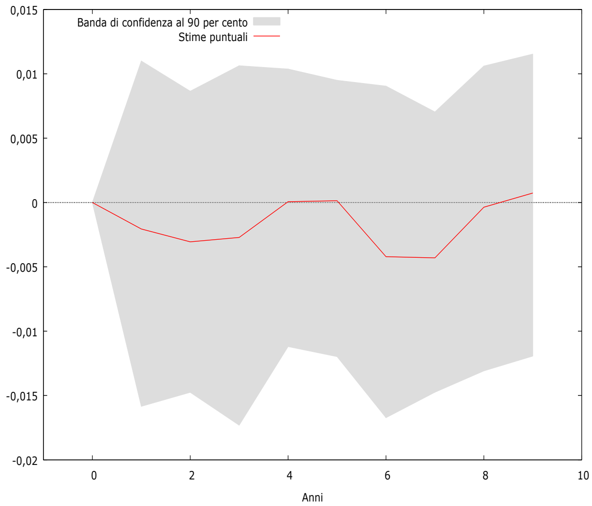
(a)



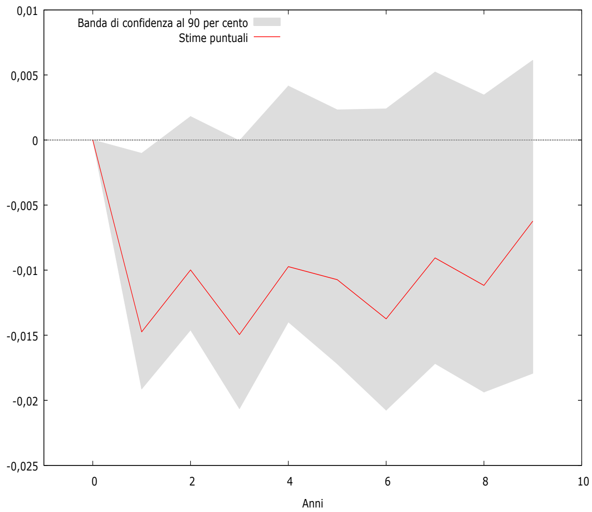

Response of *d_l_Car_reg* to one shock in *d_infl_rate*




Response of *d_l_Car_reg* to one shock in *d_l_GDPpercap*

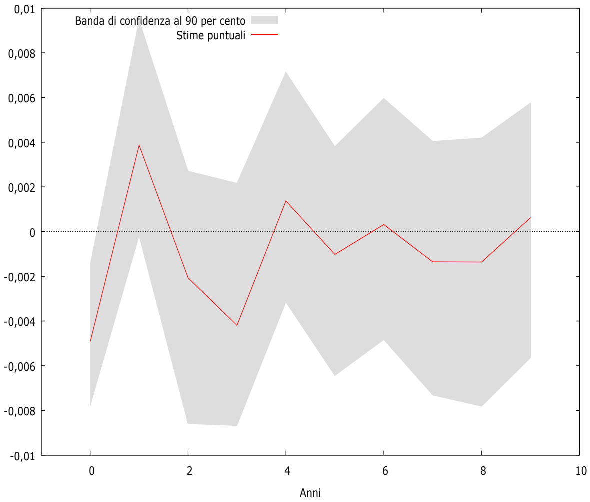



Response of *d_l_Car_reg* to one shock in *d_l_oil_price*

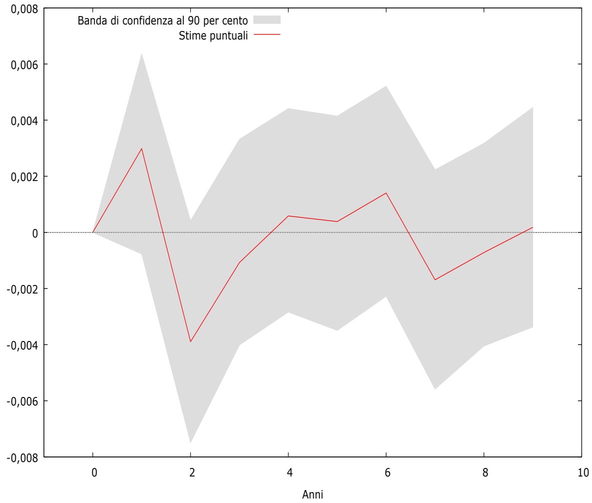



Response of *d_l_Car_reg* to one shock in *d_int_rate*

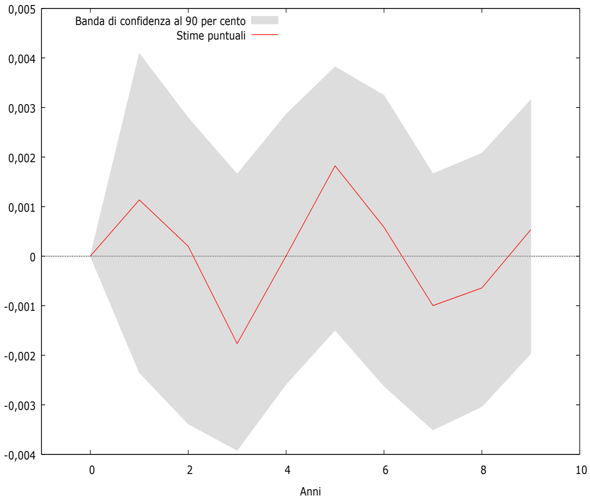
(b)



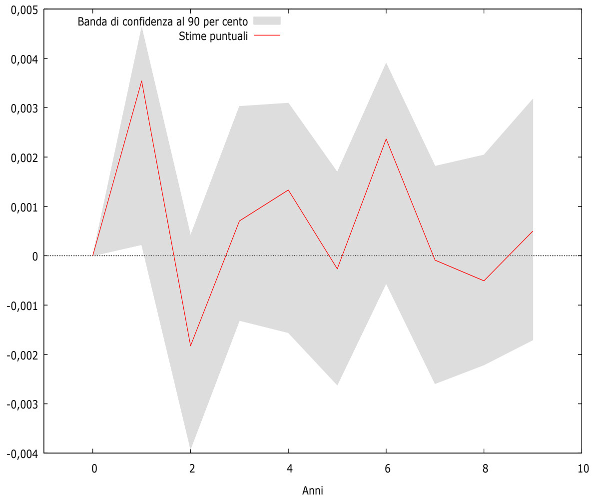

Response of *d_infl_rate* to one shock in *d_l_Car_reg*




Response of *d_infl_rate* to one shock in *d_l_GDPpercap*



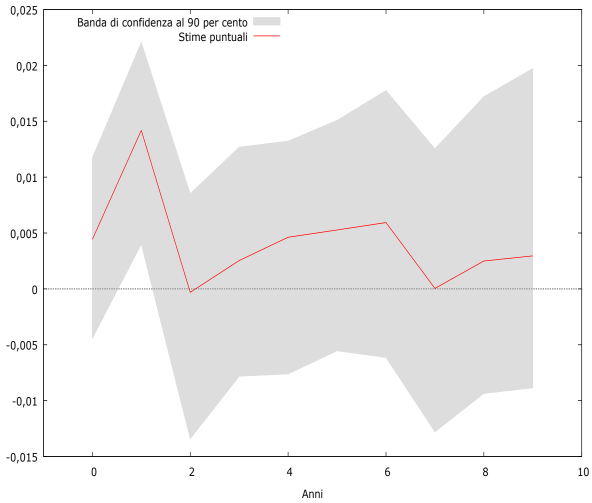

Response of *d_infl_rate* to one shock in *d_l_oil_price*



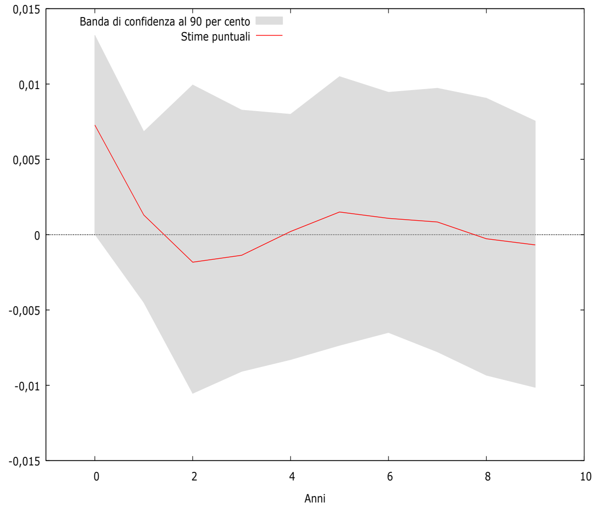

Response of *d_infl_rate* to one shock in *d_int_rate*

**Figure 18: Impulse-response functions of GDP per capita (a) and oil price (b) to one standard-deviation shock to each of the other variables**

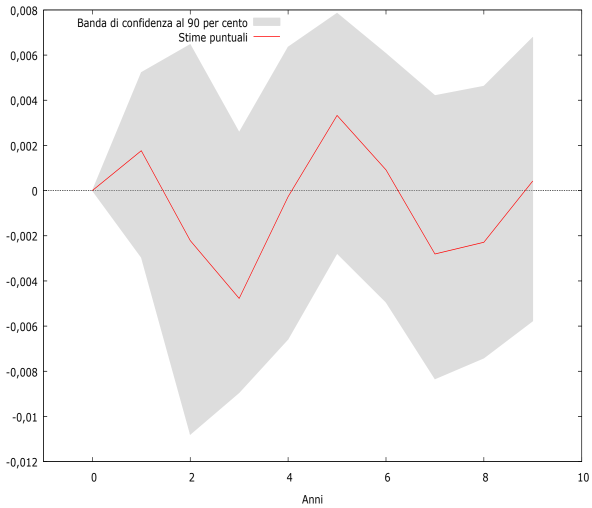
(a)



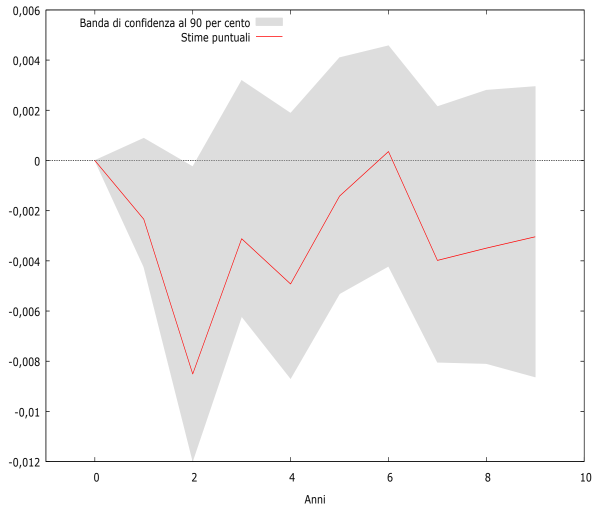

Response of *d_l_GDPpercap* to one shock in *d_l_Car_reg*




Response of *d_l_GDPpercap* to one shock in *d_infl_rate*

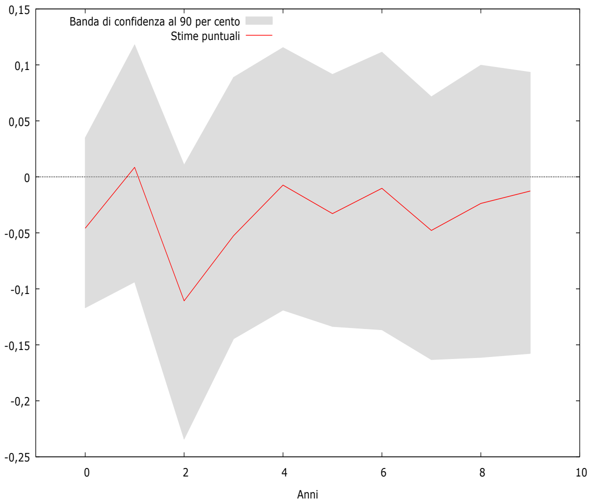



Response of *d_l_GDPpercap* to one shock in *d_l_oil_price*

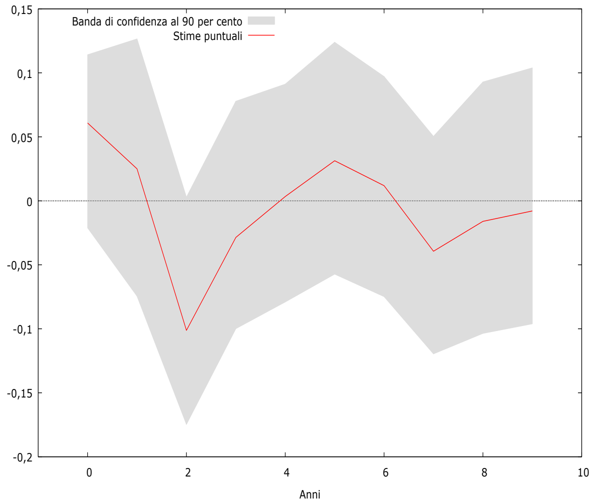



Response of *d_l_GDPpercap* to one shock in *d_int_rate*

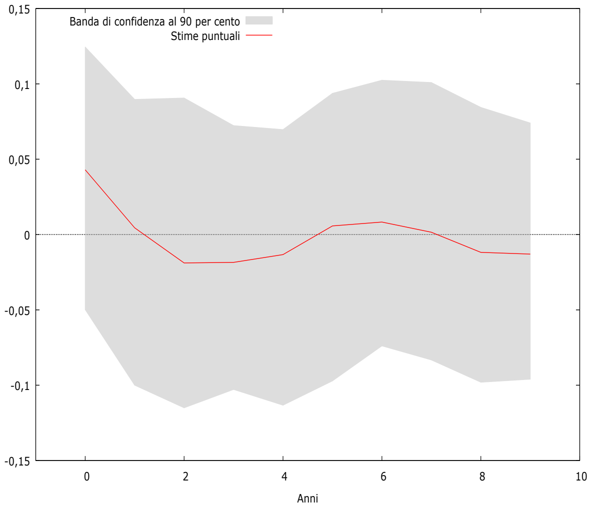
(b)



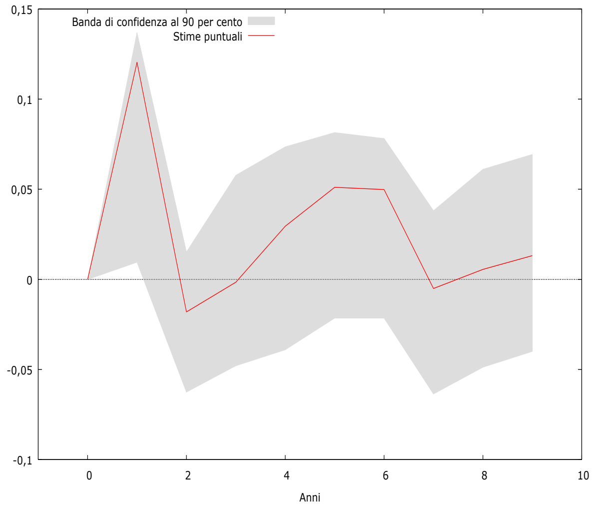

Response of *d_l_oil_price* to one shock in *d_l_Car_reg*




Response of *d_l_oil_price* to one shock in *d_l_GDPpercap*

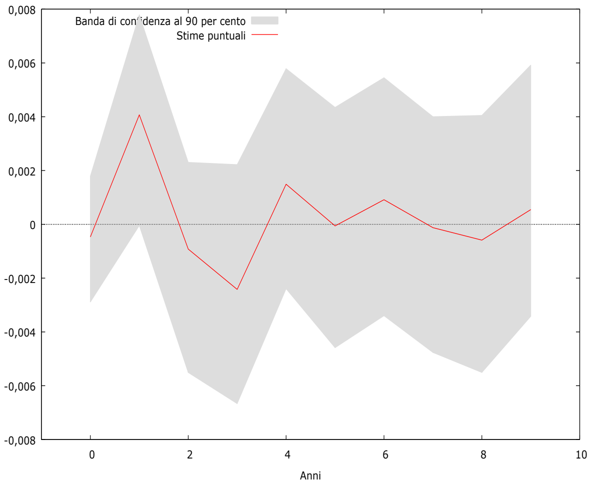



Response of *d_l_oil_price* to one shock in *d_infl_rate*

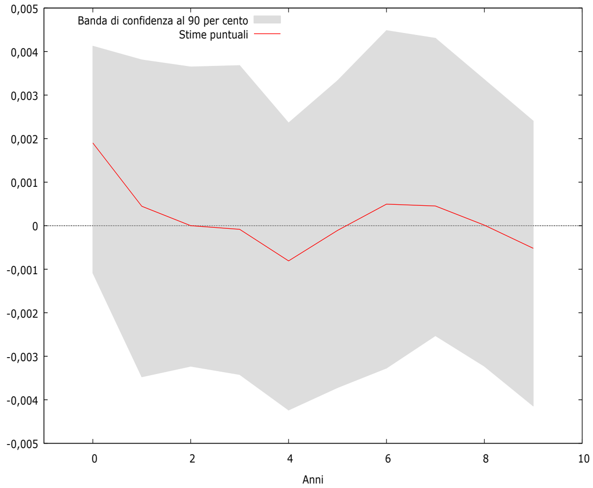



Response of *d_l_oil_price* to one shock in *d_int_rate*

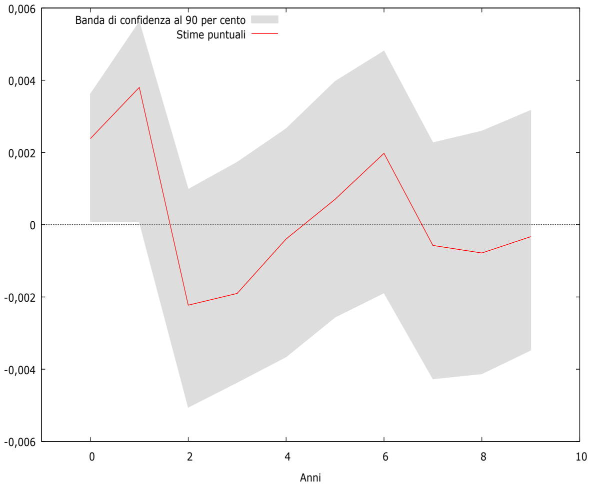
**Figure 19: Impulse-response functions of interest rate to one standard-deviation shock to each of the other variables**



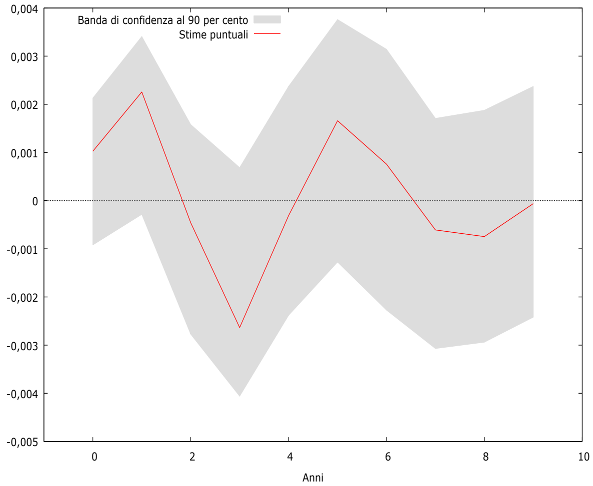

Response of *d_int_rate* to one shock in *d_l_Car_reg*




Response of *d_int_rate* to one shock in *d_infl_rate*




Response of *d_int_rate* to one shock in *d_l_GDPpercap*




Response of *d_int_rate* to one shock in *d_l_oil_price*

As regards the response of car registrations, Figure 17 shows that shocks to inflation rate negatively affect car registrations in the short-run. However, the relationship overturns between the second and the third year.

The response of car registrations to one standard deviation in GDP per capita is always positive, except for the first period of adjustment. This exception is in line with the results from VAR in Table 22, which showed that GDP per capita significantly affects *Car_reg* only with lag 2. The relationship is valid also in the opposite direction, since *Car_reg* can contribute to the rise of GDP per capita, as shown in Figure 18.

The last two plots of Figure 17 show that inflation rate and interest rate are negatively correlated with car registrations. Results are in line with the theoretical framework.

### 5.8 Forecast Error Variance Decomposition (FEVD)

Forecast Error Variance Decomposition (FEVD) is another important instrument that allows to quantify which are the most important shocks to determine the changes in a variable both in the short and in the long-term. This technique allows to discriminate the contribution of various exogenous shocks for h-step forecasting error variance of the endogenous variable.
Equation (16) summarizes this concept.

$$\omega_{kj}(h) = (\psi^2_{kj,0} + ... + \psi^2_{kj,h-1}) / \sigma^2_k(h) \qquad (16)$$

The term at the numerator of eq. (16) is the contribution of the variable j for h-step forecasting error variance for the k-th variable. In particular, this sum comes from the elements of the matrix $\Psi_n$, which is the result of the Cholesky decomposition. The denominator of eq. (16) represents the Mean Squared Error (MSE) of the h-step ahead forecasting value of $y_k$.
The main idea is that if the value of eq. (16) tends to zero, the variable j does not contain useful information to explain variable k in the future.
Table 23 reports the results for the Forecast error variance decomposition of the target *d_l_car_reg*.

**Table 23: Forecast error variance decomposition for car registrations**

| Variable | Horizon | Percent due to shocks to | | | | |
|---|---|---|---|---|---|---|
| | | d_l_Car_reg | d_infl_rate | d_l_GDPPercap | d_l_oil_price | d_int_rate |
| d_l_Car_reg | 1 | 100 | 0 | 0 | 0 | 0 |
| | 2 | 75,6732 | 2,3982 | 1,8122 | 0,3844 | 19,732 |
| | 3 | 75,8218 | 2,1332 | 2,8649 | 0,7883 | 18,3919 |
| | 4 | 69,5775 | 2,199 | 2,3664 | 0,9659 | 24,8912 |
| | 5 | 67,7297 | 2,4133 | 6,0004 | 0,7627 | 23,0939 |
| | 6 | 69,2033 | 2,032 | 5,5905 | 0,6308 | 22,5433 |
| | 7 | 65,6608 | 1,9431 | 5,209 | 1,0768 | 26,1104 |
| | 8 | 65,4024 | 1,8136 | 5,045 | 1,4724 | 26,2666 |
| | 9 | 64,475 | 1,7141 | 4,7843 | 1,384 | 27,6425 |
| | 10 | 64,2523 | 1,7052 | 5,2795 | 1,3405 | 27,4225 |

In the short-run (taking for instance period 2), innovation to *d_l_Car_reg* accounts for 75% of the fluctuation in the same variable (own shock). This means that the residual 25% of fluctuations in *d_l_Car_reg* is due to shocks in the macroeconomic variables. In particular, shock to *int_rate* can cause almost 20% fluctuation in *d_l_Car_reg*.

In the long-run (period 10), *d_l_Car_reg* contribution decreases to 64,25% while almost 35% is due to the macroeconomic environment. In particular, there is an increase in the impact of an impulse to *d_int_rate*, which can cause 27,42% fluctuation in the variance of *d_l_Car_reg*. A shock to *d_l_GDPPercapita* can cause a 5,27% fluctuation in the variance of *d_l_Car_reg*. On the contrary, contribution by inflation rate and oil price remain practically steady and irrelevant through time.

The main outcome from FEVD analysis is that interest rate is an important determinant of car registrations since it is able to explain the error variance both in the short and in the long-run. This conclusion seems to highlight the importance of monetary policy decisions. On the contrary, oil price can not influence car registrations in the short as well as in the long-run.

# 6. Country-level analysis

Another way to draw conclusions about the importance of macroeconomic shocks within the European automobile market is to estimate models using specific countries' data. In particular, this paragraph investigates data on automobile registrations, inflation rate, GDP per capita, oil price and interest rate for each of the countries that were discussed mostly in Chapter 1: Germany, UK, Italy, France and Spain. This decomposition allows to check the presence of cointegration relations and to compare the magnitude of macroeconomic shocks across different countries.

The main idea is to apply the same time-series analysis procedure to each of the selected countries' data.

## 6.1 Germany

Table 24 reports the simplest case of OLS results for data on car registrations in Germany during the last 24 years. The estimation of the coefficient of inflation rate reports a significant negative value, which is in line with theoretical framework.

**Table 24: OLS estimation for car registrations in Germany**

| Regressors | Dependent variable (l_Car_reg_Deu) |
|---|---|
| const | 19,3353<br>(3,05354)*** |
| inflrate_Deu | −5,98056<br>(2,52171)** |
| l_GDPPercapita_Deu | −0,435099<br>(0,313733) |
| l_oil_price | 0,0495809<br>(0,0634562) |
| int_rate_Deu | 2,23232<br>(1,6554) |
| Observations | T = 24 |
| SER | 0,060896 |
| R-square adjusted | 0,421120 |
| F(4, 19) | 5,182982 |

Unit root tests report interesting results showing that all the selected variables are already I(0), except for interest rate which has been differentiated once to get stationarity. This situation excludes the possibility of cointegration relationships.

Table 25 reports VAR estimation based on lag 2.

**Table 25: VAR estimation for car registrations in Germany**

| Regressors | Dependent variable | | | | |
|---|---|---|---|---|---|
| | ln(Car_reg) | infl_rate | ln(GDPPC) | ln_oil_price | Δint_rate |
| ln(Car_reg)_1 | 0,0425371<br>(0,390636) | 0,0250982<br>(0,0382197) | 0,130024<br>(0,127571) | 1,75356<br>(1,58267) | 0,0507773<br>(0,0684829) |
| ln(Car_reg)_2 | 0,0619646<br>(0,233407) | −0,000122105<br>(0,0228365) | 0,0963614<br>(0,0762243) | 0,106267<br>(0,945654) | 0,0183447<br>(0,040919) |
| infl_rate_1 | 3,63791<br>(4,56915) | 0,151881<br>(0,447045) | −1,79944<br>(1,49216) | −5,21978<br>(18,512) | −0,750386<br>(0,801024) |
| infl_rate_2 | 3,674<br>(3,32588) | −0,500956<br>(0,325404) | 0,859235<br>(1,08614) | −17,81<br>(13,4749) | −0,148908<br>(0,583065) |
| ln(GDPPC)_1 | −1,03774<br>(0,788102) | 0,0800782<br>(0,0771078) | 0,970308<br>(0,257372)*** | 7,74905<br>(3,19301)** | 0,0247038<br>(0,138163) |
| ln(GDPPC)_2 | 2,16465<br>(0,893805)** | −0,206279<br>(0,0874497)** | −0,398835<br>(0,291892) | −7,98765<br>(3,62127)** | −0,117094<br>(0,156694) |
| ln_oil_price_1 | −0,150286<br>(0,101586) | 0,0187935<br>(0,00993919)* | 0,0438466<br>(0,0331752) | 1,00681<br>(0,411579)** | 0,0182959<br>(0,0178092) |
| ln_oil_price_2 | −0,149832<br>(0,0964956) | 0,00814928<br>(0,00944112) | 0,0683748<br>(0,0315128)* | 0,0441002<br>(0,390954) | 0,00515715<br>(0,0169168) |
| Δint_rate_1 | 5,53265<br>(2,1481)** | −0,338475<br>(0,21017) | 0,169874<br>(0,70151) | −17,4358<br>(8,70308)* | 0,0503856<br>(0,376587) |
| Δint_rate_2 | −0,815355<br>(1,77424) | −0,0756199<br>(0,173591) | −1,19198<br>(0,579416)* | 1,0547<br>(7,18836) | −0,2873<br>(0,311044) |
| Observations | T = 22 | T = 22 | T = 22 | T = 22 | T = 22 |
| SER | 0,055695 | 0,005449 | 0,018188 | 0,225648 | 0,009764 |
| R-square adjusted | 0,440945 | 0,339724 | 0,984483 | 0,881738 | 0,136063 |
| F(10, 11) | 2,656341 | 2,080490 | 134,2392 | 16,65718 | 1,330732 |

Results show that GDP per capita and interest rate are short-term related to car registrations in Germany. However, the estimated coefficient for interest rate is positive, which represents a paradoxical outcome. The coefficient of interest rate for GDP per capita equation is negative and statistically significant at the 10% reliability level.

Overall, the mechanism of transmission of the monetary policy passes through GDP per capita, which in turn positively affects the performance of the automobile market in terms of new passenger cars' registrations.

Results also show that oil price coefficient is important in determining GDP per capita composition. However, the sign is not in line with the theoretical framework.

Table 26 reports the Forecast Error Variance Decomposition of *l_Car_reg* for Germany due to shocks in all other variables.

**Table 26: Forecast error variance decomposition for car registrations in Germany**

| Variable | Horizon | Percent due to shocks to | | | | |
|---|---|---|---|---|---|---|
| | | l_Car_reg | infl_rate | l_GDPPercapita | l_oil_price | d_int_rate |
| l_Car_reg | 1 | 100 | 0 | 0 | 0 | 0 |
| | 2 | 65,6635 | 1,4743 | 1,856 | 11,5184 | 19,4877 |
| | 3 | 54,7229 | 2,7376 | 3,0541 | 23,238 | 16,2475 |
| | 4 | 49,3207 | 4,6894 | 2,7077 | 27,5241 | 15,7582 |
| | 5 | 48,6456 | 4,4651 | 3,4626 | 28,3994 | 15,0273 |
| | 6 | 49,4832 | 4,3837 | 3,4 | 28,1149 | 14,6182 |
| | 7 | 49,3499 | 4,4249 | 3,4409 | 28,1226 | 14,6618 |
| | 8 | 48,782 | 4,3428 | 4,0166 | 28,3256 | 14,533 |
| | 9 | 48,5656 | 4,3805 | 4,191 | 28,3013 | 14,5616 |
| | 10 | 48,5313 | 4,4197 | 4,1946 | 28,3053 | 14,5491 |

In the short-run, macroeconomic variables account for nearly 35% of the forecast error variance at the two-time horizon. In particular, 11,51% and 19,48% are due to shocks in the oil price and the interest rate, respectively, while shocks in inflation rate and GDP per capita account for less than 2% each.

In the long-run, the magnitude of shocks in macrovariables increase to nearly 51% at the ten-time horizon. In particular, oil price contributes for nearly 28% whereas interest rate shocks for approximately 15%. Shocks to inflation rate and GDP per capita slightly increase their joint contribution to 8,5%.

### 6.2 UK

Table 27 reports the simplest case of OLS results for data on car registrations in UK during the last 21 years. The estimation of the coefficient of *l_GDPPercapita* reports a significant positive value, which denotes a strong correlation between the automobile market and the level of income per capita in UK. The other coefficients report the expected negative sign, but they are not statistically significant at the 10% reliability value.

**Table 27: OLS estimation for car registrations in UK**

| Regressors | Dependent variable (l_Car_reg_UK) |
|---|---|
| const | 9,81299<br>(1,28189)*** |
| inflrate_UK | −2,44444<br>(2,15969) |
| l_GDPPercapita_UK | 0,510768<br>(0,141431)*** |
| l_oil_price | −0,105584<br>(0,0626991) |
| int_rateUK | −0,173542<br>(0,806136) |
| Observations | T = 21 |
| SER | 0,048786 |
| R-square adjusted | 0,762267 |
| F(4, 16) | 17,03197 |

Unit root tests denote that all variables are integrated of order one I(1), except for *l_GDPPercapita* which is I(2). Therefore, the first difference is used in the VAR model.

The cointegration analysis based on Engle-Granger and Johansen tests does not show any evidence of long-term equilibrium relationship for car registrations in UK. Therefore, as in the aggregate case, a VAR in first differences is the proper model representation.

Table 28 reports VAR estimation for *d_l_Car_reg_UK* based on lag 2.

**Table 28: VAR estimation for car registrations in UK**

| Regressors | Dependent variables | | | | |
|---|---|---|---|---|---|
| | Δln(Car_reg) | Δinfl_rate | $\Delta^2$ln(GDPPC) | Δln_oil_price | Δint_rate |
| Δln(Car_reg)_1 | 0,0856063 (0,431361) | 0,0281818 (0,0917002) | −0,98724 (0,783856) | 1,85707 (3,27719) | 0,129057 (0,153433) |
| Δln(Car_reg)_2 | 0,609268 (0,334095) | −0,122305 (0,0710232) | 0,763619 (0,607108) | −3,40767 (2,53823) | −0,0298722 (0,118836) |
| Δinfl_rate_1 | −5,86157 (2,26938)** | 0,243734 (0,482432) | −3,5109 (4,12384) | −0,786468 (17,2412) | 0,160843 (0,807208) |
| Δinfl_rate_2 | −0,152331 (2,47847) | −0,0732366 (0,526882) | −3,92352 (4,5038) | 10,5482 (18,8298) | 0,645643 (0,881583) |
| $\Delta^2$ln(GDPPC)_1 | 0,0337234 (0,291708) | −0,00787254 (0,0620122) | 0,484158 (0,530082) | −0,186444 (2,2162) | 0,0723024 (0,103759) |
| $\Delta^2$ln(GDPPC)_2 | 0,288732 (0,205846) | −0,0436338 (0,0437594) | 0,660172 (0,374056) | 1,39334 (1,56388) | 0,0503149 (0,0732184) |
| Δln_oil_price_1 | 0,140223 (0,0675172)* | −0,00983034 (0,014353) | −0,102229 (0,12269) | 0,076587 (0,51295) | 0,00710686 (0,0240156) |
| Δln_oil_price_2 | 0,124145 (0,086284) | −0,00114266 (0,0183425) | 0,0415735 (0,156793) | −1,07549 (0,655528) | −0,0176268 (0,0306909) |
| ΔInt_rate_1 | −3,14089 (1,37986)* | 0,275837 (0,293334) | −7,44933 (2,50743)** | −4,29697 (10,4832) | −0,348727 (0,490809) |
| ΔInt_rate_2 | −1,59773 (1,54865) | −0,145255 (0,329216) | 1,13741 (2,81415) | 7,31631 (11,7656) | 0,24415 (0,550847) |
| Observations | T = 17 | T = 17 | T = 17 | T = 17 | T = 17 |
| SER | 0,043697 | 0,009289 | 0,079404 | 0,331978 | 0,015543 |
| R-square adjusted | 0,508213 | -0,022915 | 0,294897 | -0,507958 | -0,553724 |
| F(10, 6) | 2,653444 | 0,964158 | 1,669172 | 0,461037 | 0,429784 |

Results show that inflation rate is an important short-term determinant of car registrations in UK. The coefficient reports the expected negative sign, showing that the increase in inflation reduces the purchasing power of consumers in the automobile market. A similar result comes from the interest rate's negative coefficient, confirming that levels of interest rate set by Bank of England is an important determinant of automobile market's performances.

The significant positive coefficient of oil price is not in line with the theoretical framework. As regards GDP per capita, results show a positive correlation which is not statistically significant at the 10% reliability level.

Table 29 reports the Forecast Error Variance Decomposition of *d_l_Car_reg* for UK due to shocks in all other variables.

**Table 29: Forecast error variance decomposition for car registrations in UK**

| Variable | Horizon | Percent due to shocks to | | | | |
|---|---|---|---|---|---|---|
| | | d_l_Car_reg | d_infl_rate | d_d_l_GDPPercap | d_l_oil_price | d_int_rate |
| d_l_Car_reg | 1 | 100 | 0 | 0 | 0 | 0 |
| | 2 | 53,3127 | 10,1144 | 7,8889 | 14,5766 | 14,1073 |
| | 3 | 38,3296 | 7,1607 | 7,5453 | 26,5385 | 20,426 |
| | 4 | 44,5922 | 16,123 | 5,3958 | 18,8589 | 15,0301 |
| | 5 | 40,587 | 25,8575 | 4,5162 | 15,7795 | 13,2598 |
| | 6 | 39,8691 | 27,107 | 4,2195 | 14,6441 | 14,1604 |
| | 7 | 42,928 | 27,6367 | 3,6257 | 12,8151 | 12,9946 |
| | 8 | 43,4715 | 27,5519 | 3,2724 | 12,4507 | 13,2534 |
| | 9 | 45,222 | 27,2478 | 2,9418 | 11,4637 | 13,1247 |
| | 10 | 46,0778 | 29,1823 | 2,4874 | 9,672 | 12,5806 |

In the short-run, macroeconomic variables contribute to almost 47% of the error variance of *d_l_Car_reg* in UK at two-time horizon. In particular, shocks in inflation rate and GDP per capita account for 10,11% and 7,8%, respectively. A higher contribution is brought by oil price and interest rate shocks, which account both for nearly 14%.

In the long-run, the situation overturns because macroeconomic variables shocks account for 54% of car registrations' error variance. In particular, inflation rate shocks account for nearly 20%. Meanwhile, the magnitude of shocks in the other macrovariables decreases or remains steady.

### 6.3 Italy

Table 30 reports the simplest case of OLS results for data on car registrations in Italy during the last 21 years. Results show strong and expected signs for the coefficients of GDP per capita and oil price. As regards interest rate, the coefficient is not in line with theoretical framework.

**Table 30: OLS estimation for car registrations in Italy**

| Regressors | Dependent variable (l_Car_reg_ita) |
|---|---|
| const | −9,9007<br>(5,04279)* |
| inflrate_ita | 0,465286<br>(3,98909) |
| l_GDPPercapita_Ita | 2,60411<br>(0,524056)*** |
| l_oil_price | −0,561357<br>(0,108508)*** |
| int_rate_ita | 5,37012<br>(2,50212)** |
| Observations | T = 21 |
| SER | 0,128728 |
| R-square adjusted | 0,621533 |
| F(4, 16) | 9,211178 |

Unit root tests were performed. All variables are integrated of order one I(1). Therefore, the cointegration analysis is conducted. According to Johansen’s approach, no cointegration relationship is found for car registrations in Italy when considering all variables in the trace test. However, a remarkable cointegration relationship is found by considering only inflation rate and GDP per capita as explanatory variables.

Table 31 reports the Johansen trace test for cointegration adjusted for the size of the sample (T = 19 and 12 degrees of freedom), in the case of an unrestricted constant (Case 3 for Johansen's list).

**Table 31: Trace test for cointegration on car registrations in Italy**

| Rank | Eigenvalues | Trace Test | p-value |
|---|---|---|---|
| 0 | 0,86219 | 52,887 | 0,0008 |
| 1 | 0,49555 | 15,232 | 0,0987 |
| 2 | 0,11074 | 2,23 | 0,1837 |

Therefore, there is only one cointegration relationship in the data. The question is to define the correct direction of the causality in the Granger sense.

Table 32 represents the Vector Error Correction Model (VECM) for Italy.

**Table 32: Vector Error Correction Analysis for Italy with one cointegration relationship**

| Regressors | Dependent variable | | |
|---|---|---|---|
| | d_l_Car_reg_Ita | d_inflrate_ita | d_l_GDPPercapita_Ita |
| d_l_Car_reg_Ita_1 | −0,473130<br>(0,308347) | 0,00707005<br>(0,0266693) | −0,0145050<br>(0,0661882) |
| d_inflrate_ita_1 | −5,91697<br>(2,39130)** | 0,200528<br>(0,206826) | −0,678248<br>(0,513304) |
| d_l_GDPPercapi~_1 | 2,66121<br>(1,10661)** | 0,154670<br>(0,0957115) | 0,646549<br>(0,237538)** |
| ECT_1 | −1,62129<br>(3,68529) | −1,08562<br>(0,318745)*** | −1,05705<br>(0,791066) |
| Observations | T = 19 | T = 19 | T = 19 |
| SER | 0,090364 | 0,007816 | 0,019397 |
| R-square adjusted | 0,383456 | 0,452732 | 0,437221 |

Results for the 3-variables VECM estimation show that, in the long-term, the ECT-1 coefficient of *d_l_Car_reg_Ita* is not statistically significant. Instead, the ECT-1 coefficient for *d_inflrate_Ita* shows a strong statistical significance at 1% reliability level. This result shows that inflation rate is likely to include an error correction mechanism, which depends on short-term deviations of car registrations and GDP per capita. The error correction term's coefficient ($\alpha$ = -1,08) represents the speed of adjustment to achieve a balance in the long-term.

Phillips' normalization allows to develop the long-term theoretical equilibrium relationship for inflation rate, which is reported in equation (17).

$$\inf rate\_ita = \underset{(0,00391)}{0,0089965} l\_Carreg\_ita + \underset{(0,00806)}{0,024887} l\_GDPPC\_ita \quad (17)$$

Both coefficients are statistically significant and show positive signs. This means that car registrations and GDP per capita go at the same pace with the overall level of consumer prices in Italy.

However, the aim is to define a long-term relationship for the main variable object of interest. Thus, Phillips' normalization for *l_Car_reg_ita* brings to the determination of eq. (18).

$$l\_Carreg\_ita = \underset{(12,745)}{111,15} \inf rate\_ita - \underset{(0,8790)}{2,7663} l\_GDPPC\_ita \quad (18)$$

Results report significant coefficients that are not in line with the theoretical framework. Therefore, inflation rate and GDP per capita are not useful to explain levels of car registrations in Italy in the long-run. The negative coefficient for *l_GDPPC_ita* could be ultimately justified by the strong negative impact of the outbreak of recent financial crisis.

Table 32 is also useful for considerations about short-term linkages. As a matter of fact, both inflation rate and GDP per capita are significantly related with car registrations in Italy in the short-run. The estimated coefficients report the expected sign and are both significant at the 5% reliability level.

Table 33 reports the results for the forecast error-variance decomposition of *l_Carreg_ita*.

**Table 33: Forecast error variance decomposition for car registrations in Italy**

| Variable | Horizon | Percent due to shocks to | | |
|---|---|---|---|---|
| | | infl_rate_ita | l_Car_reg_ita | l_GDPPC_ita |
| l_Car_reg_ita | 1 | 68,6441 | 31,3559 | 0 |
| | 2 | 61,0725 | 33,7161 | 5,2115 |
| | 3 | 57,857 | 36,457 | 5,6859 |
| | 4 | 52,763 | 40,5521 | 6,685 |
| | 5 | 48,5599 | 43,6498 | 7,7903 |
| | 6 | 46,1911 | 45,1504 | 8,6585 |
| | 7 | 44,6606 | 46,1581 | 9,1814 |
| | 8 | 43,274 | 47,1553 | 9,5707 |
| | 9 | 42,0927 | 47,9971 | 9,9103 |
| | 10 | 41,2161 | 48,5908 | 10,1931 |

### 6.4 France

Unit root tests denote that all variables for France are integrated of order one I(1). Therefore, the cointegration analysis is performed. According to Johansen's approach, two cointegration relationships are found showing that two equations can be developed in the long-term.

Table 34 reports the Johansen trace test for cointegration adjusted for the size of the sample (T = 24 and 13 degrees of freedom), in the case of an unrestricted constant (Case 3 for Johansen's list).

**Table 34: Trace test for cointegration for car registrations in France**

| Rank | Eigenvalues | Trace Test | p-value |
|---|---|---|---|
| 0 | 0,80303 | 103,85 | 0,0329 |
| 1 | 0,71241 | 64,859 | 0,0339 |
| 2 | 0,56839 | 34,949 | 0,0598 |
| 3 | 0,30536 | 14,784 | 0,1066 |
| 4 | 0,22247 | 6,0392 | 0,0276 |

Therefore, the rank of the matrix is equal to two. The question now is to define the direction of the causality in the Granger sense.

Table 35 represents the Vector Error Correction Model (VECM) for car registrations in France.

**Table 35: Vector Error Correction Analysis for France with two cointegration relationships**

| Regressors | Dependent variable | | | | |
|---|---|---|---|---|---|
| | d_l_Car_reg _Fra | d_l_GDPPercapita_Fra | d_inflrate_Fra | d_int_rate_Fra | d_l_oilprice |
| d_l_Car_reg_Fra_1 | −0,219572 (0,290526) | −0,131851 (0,0548783)** | −0,059552 (0,0201084)*** | −0,0129447 (0,047349) | −0,801534 (0,798312) |
| d_l_GDPPercapi~_Fra_1 | −2,38844 (1,41908) | 1,1046 (0,268054)*** | 0,312067 (0,0982197)*** | 0,235614 (0,231277) | 10,3537 (3,89937)** |
| d_inflrate_Fra_1 | 5,07811 (2,96367) | −1,74963 (0,559818)*** | −0,447856 (0,205127)** | −0,98994 (0,483011)* | −10,0661 (8,14364) |
| d_int_rate_Fra_1 | −0,100438 (1,68885) | −0,368112 (0,319013) | −0,131145 (0,116892) | 0,0352568 (0,275244) | −4,9206 (4,64066) |
| d_l_oil_price_1 | 0,0589569 (0,104658) | −0,00206881 (0,0197691) | −0,00120143 (0,00724375) | 0,0158333 (0,0170568) | 0,00069757 (0,28758) |
| ECT_1 | −0,606013 (0,284276)** | 0,119442 (0,0536979)** | 0,0921915 (0,0196758)*** | 0,0712976 (0,0463305) | 2,22306 (0,78114)** |
| ECT_2 | 1,03879 (0,29052)*** | −0,0286349 (0,0548778) | 0,0314114 (0,0201082) | −0,0690828 (0,0473486) | −0,0051243 (0,798305) |
| Observations | T = 24 | T = 24 | T = 24 | T = 24 | T = 24 |
| SER | 0,074232 | 0,014022 | 0,005138 | 0,012098 | 0,203976 |
| R-square adjusted | 0,371689 | 0,373094 | 0,632166 | 0,028730 | 0,326462 |

Results on VECM analysis enable to detect the long-term dynamics between French automobile market and macroeconomics. Coefficients of both error correction terms reveal significant error correction mechanisms for *l_Car_reg*. This means that *infl_rate*, *l_GDPPercapita*, *l_oil_price* and *int_rate* are simultaneously able to explain fluctuations in *l_Car_reg* in the long-run. The coefficient of ECT_1 ($\alpha$ = - 0,60) for equation of *d_l_Car_reg* reveals the speed of adjustment of corrections in the short-term to restore the long-term equilibrium.

Phillips' normalization allows to develop the long-term theoretical equilibrium relationship for car registrations in France. In order to interpret the coefficients properly, some preliminary hypothesis is made.

Haugh et al. (2010) indicate that financial conditions significantly affected all G7 countries' car registrations during the period across the recent financial crisis, except for France. The idea is to exploit this finding by restricting VECM with the first hypothesis that $\beta$ (*int_rate_fra*) = 0 in the long-term trend of car registrations. Moreover, the additional restriction is about the other detected cointegration equation. By selecting GDP per capita as the other dependent variable in the long-run model, the second hypothesis is to neutralize the effect of oil price over GDP per capita.

The findings related to cointegration analysis for France are summarized in the following equations, based on the hypothesized Phillips' normalizations.

$$\begin{aligned} l\_Carreg\_fra &= \underset{(0,0535)}{-0{,}1774}\, l\_GDPPC\_fra + \underset{(1,8348)}{7{,}873}\, \mathrm{inf}rate\_fra + \underset{(0,012067)}{0{,}04595}\, l\_oilprice \\ l\_GDPPC\_fra &= \underset{(0,3692)}{11{,}269}\, l\_Carreg\_fra - \underset{(19,039)}{57{,}480}\, \mathrm{inf}rate\_fra - \underset{(2,1241)}{13{,}78}\, \mathrm{int}rate\_fra \end{aligned} \quad (19)$$

According to eq. (19), there is no evidence of simultaneous two-way positive relationship between GDP per capita and car registrations in France. On one hand, the estimated $\beta$ for the first expression is negative partly because of the impact of recent financial crisis that outweighs periods of positive correlation between the two variables. On the contrary, the second expression reports a positive and significant coefficient showing that positive performances of the automobile market contribute to improve the average level of consumers' wealth. Additionally, the first expression reports positive and significant estimations for the coefficients related to the inflation rate and oil price. This result is not in line with the theoretical framework since increase in the level of prices should bring to lower levels of consumers' demand.

Finally, the second expression reports negative and significant estimations for coefficients related to the inflation rate and interest rate, which are in line with the general economic assumptions.

Table 36 reports the results for the forecast error variance decomposition of car registrations in France. In the long-run, shocks in oil price can cause nearly 36% of fluctuations in car registrations in France.

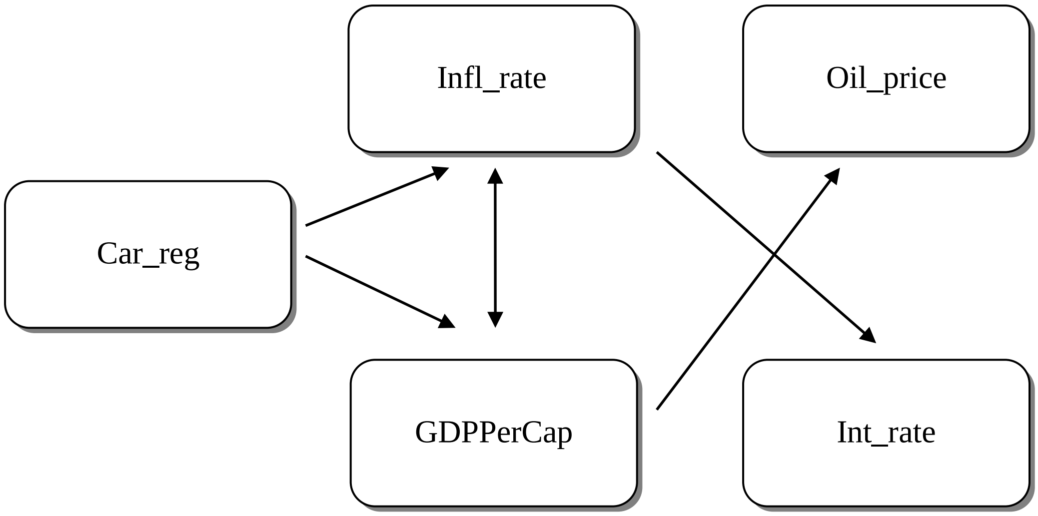
**Table 36: Forecast error variance decomposition for car registrations in France**

| Variable | Horizon | Percent due to shocks to | | | | |
|---|---|---|---|---|---|---|
| | | l_Car_reg | l_GDPPercap | infl_rate | l_oil_price | int_rate |
| l_Car_reg | 1 | 100 | 0 | 0 | 0 | 0 |
| | 2 | 67,6281 | 0,7122 | 0,0394 | 26,9993 | 4,621 |
| | 3 | 55,6809 | 0,7598 | 0,3914 | 39,9222 | 3,2458 |
| | 4 | 46,0591 | 1,2183 | 3,2314 | 46,8469 | 2,6443 |
| | 5 | 45,4918 | 2,2364 | 3,4692 | 46,1685 | 2,6341 |
| | 6 | 46,1497 | 3,6997 | 3,4166 | 44,1533 | 2,5808 |
| | 7 | 47,9916 | 5,1175 | 3,1724 | 41,3164 | 2,4021 |
| | 8 | 49,5674 | 6,2429 | 2,9732 | 38,9743 | 2,2422 |
| | 9 | 50,8578 | 7,0409 | 2,7873 | 37,2 | 2,1141 |
| | 10 | 51,6975 | 7,6177 | 2,6112 | 36,0745 | 1,9992 |

VECM analysis is also useful for short-term dynamics. Results from Table 35 show that there is a strong short-term two-way relationship between GDP per capita and inflation rate. Meanwhile, *l_Car_reg* is both short-term related to GDP per capita and inflation rate. At last, the short-term significant linkage between *l_Car_reg* and GDP per capita is not in line with the theoretical framework.

Figure 20 summarizes the findings about Granger short-run dynamics.

**Figure 20: Granger short-term causal relationship for France**




## 6.5 Spain

Table 37 reports the simplest case of OLS results for data on car registrations in Spain during the last 21 years. Results show that all coefficients report the expected sign, except for inflation rate.

**Table 37: OLS estimation for car registrations in Spain**

| Regressors | Dependent variable (l_Car_reg_esp) |
|---|---|
| const | −1,82031<br>(4,14397) |
| inflrate_esp | 10,2352<br>(4,23992)** |
| l_GDPPercapita_Esp | 1,85913<br>(0,462227)*** |
| l_oil_price | −0,761385<br>(0,162484)*** |
| int_rate_Esp | −2,55865<br>(3,60011) |
| Observations | T = 21 |
| SER | 0,184874 |
| R-square adjusted | 0,538263 |
| F(4, 16) | 6,828665 |

Unit root tests reveal that all variables are integrated of order one, except for *l_GDPPercapita_esp* that needs to be differentiated twice to get stationarity. Therefore, the first difference is used for VAR and cointegration analysis.

According to Johansen's approach, two cointegration relationships are found showing that two equations can be developed in the long-term. However, this result is valid only when interest rate is left apart. Therefore, interest rate is excluded by the VECM specification.

Table 38 reports the Johansen trace test for cointegration adjusted for the size of the sample (T=18 and 11 degrees of freedom), in the case of an unrestricted constant (Case 3 for Johansen's list). The rank of the matrix is equal to 2.

**Table 38: Trace test for cointegration on car registrations in Spain**

| Rank | Eigenvalues | Trace Test | p-value |
|---|---|---|---|
| 0 | 0,97874 | 117,39 | 0,0001 |
| 1 | 0,85480 | 48,081 | 0,0114 |
| 2 | 0,41312 | 13,347 | 0,2020 |
| 3 | 0,18826 | 3,7544 | 0,0984 |

Table 39 reports the VECM analysis for Spain.

**Table 39: Vector Error Correction Analysis for Spain with two cointegration relationships**

| Regressors | Dependent variables | | | |
|---|---|---|---|---|
| | d_l_Car_reg_Esp_1 | d_inflrate_esp_1 | d_d_l_GDPPerca~_1 | d_l_oil_price_1 |
| d_l_Car_reg_Esp_1 | 0,62201<br>(0,455377) | −0,0051944<br>(0,0445291) | 0,0780348<br>(0,0383729)* | −1,45177<br>(0,657767)* |
| d_inflrate_esp_1 | −5,36415<br>(5,98686) | −1,26925<br>(0,585426)* | −2,18358<br>(0,50449)*** | −30,3718<br>(8,64769)*** |
| d_d_l_GDPPerca~_1 | 0,693439<br>(3,28139) | 0,517574<br>(0,320871) | 0,58674<br>(0,276511)* | 20,0618<br>(4,73979)*** |
| d_l_oil_price_1 | 0,0830723<br>(0,21439) | 0,0276577<br>(0,0209641) | 0,05382530<br>(0,0180658)** | 0,597359<br>(0,309675)* |
| ECT_1 | −1,8042<br>(2,3095) | −0,311023<br>(0,225834) | −0,716094<br>(0,194613)*** | −12,1239<br>(3,33594)*** |
| ECT_2 | −0,0485346<br>(0,0954066) | −0,0154247<br>(0,0093293) | −0,0228493<br>(0,0080397)** | −0,596912<br>(0,13781)*** |
| Observations | T = 18 | T = 18 | T = 18 | T = 18 |
| SER | 0,134847 | 0,013186 | 0,011363 | 0,194779 |
| R-square adjusted | 0,107940 | 0,113078 | 0,781663 | 0,521070 |

Results from Table 39 show that, in the long-run, the ECT coefficients of *l_Car_reg_esp* are not statistically significant. On the contrary, coefficients of both $ECT_s$ for the last two columns show a strong correlation at the 5% reliability level. As regards oil price equation, coefficients of error correction terms shows statistical significance even at 1% reliability level.

Phillips' normalization allows to develop the two long-term theoretical equilibrium relationships on the basis of some preliminary restrictions. The idea is to evaluate a long-term equilibrium relationship for the main variables of interest, *l_Car_reg_esp* and *d_l_GDPPercapita_esp*. In order to identify the model properly, two additional restrictions have to be set. In the first equation, the impact of inflation rate over car registrations in Spain is set to zero, while in the second equation the coefficient of oil price is set to zero.

Equation (21) reports the two theoretical cointegration relationships object of interest.

$$\begin{aligned} l\_Carreg\_esp &= \underset{(0,4532)}{-3,716}\, d\_l\_GDPPC\_esp + \underset{(0,01597)}{0,1391}\, l\_oilprice \\ d\_l\_GDPPC\_esp &= \underset{(0,00482)}{-0,1229}\, l\_Car\_reg\_esp + \underset{(0,1481)}{0,829}\, \inf\_rate\_esp \end{aligned} \tag{20}$$

All the estimations of parameters in equation (20) show statistical significance, except for the coefficient of oil price in the first expression. In the long-run, the first difference of GDP per capita is negatively related with levels of car registrations. The opposite is also true. The coefficient of oil price reveals a positive relationship with car registrations in Spain. However, this last result is not in line with theoretical background research.

Eventually, equation (20) shows some ambiguous results. The coefficients' estimations seem to denote a negative relationship between the levels of car registrations and GDP per capita in Spain in the last two decades. This outcome might be due to the strong negative effect of the recent financial crisis, which has been determinant in affecting the performance of the automobile market in Spain.

# Conclusions

This thesis investigates the impact of macroeconomic variables – inflation rate, GDP per capita, oil price and interest rate – over the performances of automobile markets in the European countries during the last 25 years. The aim is to confirm empirically that automobile markets in countries like France, Italy and Spain are tied mostly with long-term structural macroeconomic conditions. The approach used in this work follows the standard way of proceeding of time series analysis based on unit root tests, cointegration analysis and the implementation of the proper model (VAR and VECM). This type of modelling is useful for two reasons. On one hand, it allows to make some focus on dynamics by discriminating between short and long-run effects. On the other hand, the simultaneous presence of all the equations enables to study the magnitude of unexpected impulses in the error terms over automobile sales' model through time. Additionally, Impulse-response analysis and Forecast Error Variance Decomposition are used for detecting the extent to which variables move and react each other.

Firstly, there is evidence of long-run error correction mechanisms for some of the countries under object of investigation. In particular, the VECM analysis for France shows that car registrations include a significant error correction term, which in turn is driven by short-term deviations of the selected macroeconomic variables. Under some strict hypothesis based on the observation and previous findings – as the one reported by Haugh et al. (2010) concerning the interest rate's neutral effect over French car registrations – the estimated cointegration equation reports an unexpected negative link between GDP per capita and car registrations in France. In spite of this, the reverse linkage between car registrations and GDP per capita reveals a significant positive relationship. This outcome might be partially due to the strong impact of the three industry-specific crises that occurred in France during the last 25 years. These falls might outweigh the positive impact of the constant increase in levels of consumers' disposable income. Moreover, the sign for estimated long-term coefficients of both inflation rate and oil price with respect to car registrations is positive. This result contradicts the economic theory and the findings by Lee and Ni (2002) and Busse et al. (2009), which indicate that the increase in the level of prices causes a reduction in the level of consumers' consumption. A possible explanation of this paradoxical result might be due to the choice of using oil price as an indicator of the cost of raw materials and fuel expenditure rather than data on real price of fuel at the pump.

One cointegration relationship is found for data on Italy. The Phillips' normalization for car registrations reports a negative coefficient for GDP per capita and a positive one for inflation rate. Both results are not in line with the theoretical framework and might be due to the negative impact of recent financial crisis. Estimations also show that levels of car registrations and GDP per capita are likely to take part to the error correction term of the inflation rate equation.

The cointegration analysis for data on Spain detect two long-term equilibrium relationships. In this case, results are ambiguous. Estimations report a negative two-way relationship between car registrations and GDP per capita. As in the case of France and Italy, this outcome may be linked to the industry-specific crises that mostly determine the cycles of new passenger car registrations.

Secondly, shocks to GDP per capita increase the levels of car registrations in the short-run in all European automobile markets. Results are in line with model framework presented by Dargay (2001), Haugh et al. (2010) and Muhammad et al. (2013) showing that disposable income is the most important factor in determining consumers' demand for automobiles. This effect is strong for aggregate European data, Germany and Italy and generally takes place with a lag of two years at most. Interestingly, the reverse relationship of car registrations towards GDP per capita is also true for the European automobile market as a whole, confirming the underlying theory of business cycles cited by Gaspareniene et al. (2014). As concerns UK and Spain, coefficients of GDP per capita are positive but not properly statistically significant. As regards France, short-run coefficients' estimations reveal a negative relationship between car registrations and GDP per capita. This outcome strengthens the magnitude of the three crises episodes that affected French automobile market in the last 25 years. Overall, the Forecast error variance decomposition shows that shocks to GDP per capita contribute to nearly 5-10% of fluctuations in car registrations in each country.

Thirdly, shocks to inflation rate tend to diminish the purchasing power of consumers in the short-run. This effect is significant with a lag of two for aggregate data on Europe, UK and Italy. Hence, the overall inflation has a direct effect on both disposable income and, indirectly, on the demand for passenger vehicles in the economy. These findings are in line with the short-term considerations included in the research by Muhammad et al. (2013).

Finally, estimations about short-term effects of interest rate over car registrations are partially in line with the underlying theory.

On one hand, for aggregate data on Europe, Germany and UK results confirm the idea of the credit channel theory based on the findings reported by Ludvigson (1998). Even though data on EU15+EFTA registrations indicate that the coefficient of interest rate is negative but not statistically significant, FEVD analysis reveals that impulses in interest rate account for nearly 20% of fluctuations in European car registrations in the short-run.

Short-run coefficients for Germany and UK reveal even more robustness. As regards Germany, there's evidence about the positive impact of a decrease in the short-term interest rates and a corresponding increase in GDP per capita with a lag of two periods. Hence, an improvement in consumers' disposable income indirectly raises the automobile consumption opportunities and car sales. As concerns UK, a falling interest rate has a direct positive effect on car registrations. FEVD analysis reports that shocks in interest rate account for 14% of fluctuations of car registrations in UK.

Therefore, data on Germany and UK strongly confirm that a more accommodative monetary policy is likely to produce an increase in the supply of consumers' loans, which in turn stimulates the purchase of new automobiles.

On the other hand, data on Italy, France and Spain are likely to indicate that firms and consumers are less sensitive to the European Central Bank's monetary policy strategies. In these countries, demand for automobiles could be driven by long term structural features that are not explained by standard macroeconomic indicators. This last consideration is in line with the discussion by Lee-Makiyama (2012), who highlighted the double nature of the European automobile market.

In conclusion, this thesis underlines the role of macroeconomic variables showing that they are an important source of uncertainty in the evolution of car registrations over the European automobile markets. Results show that they account for 25% of fluctuations of car registrations in the short-run. However, as suggested by Barber et al. (1999), there is a wide residual range of factors – firm-specific commercial and marketing policies, industrial dynamics – that drive car sales within the economies.

Despite of the obtained results, some limits of this research might be underlined. First, the number of observations per variable is limited to the choice of the frequency of data. The results might differ by selecting data with higher frequency, such as quarterly or monthly data. This choice would enlarge the size of the sample and simplify the implementation of cointegration tests and impulse-response analysis. Second, the selection of variables might be adapted. For instance, a more representative variable for real consumers' fuel price could be chosen. In doing so, this new indicator would control for the impact of national taxation (taxes and duties), which is different across countries and derives from specific national fiscal decisions. Third, a model of a more open economy might be considered. The preliminary research reported in Chapter 1 confirmed that the European automobile industry has a strong degree of openness in terms of exports but not keen on imports. Thus, the introduction of a variable measuring the degree of trade openness could explain the extent to which more export-oriented countries are safeguarded against sudden falls in internal consumers' demand. This intuition would help to model the realistic case of an open automotive industry.

Finally, the results reported in this thesis might be linked to the adoption of time series approach, which is focused on temporal dynamics. Thus, the implementation of a procedure based on Panel data would be straightforward in combining both the time series and the cross-sectional natures of data coming from observations.

Even so, this research aims to stress the double nature of the European economy as a whole, in which northern countries are likely to be more sensitive to markets' short-term fluctuations and impulses coming from central monetary policy decisions. On the other side, southern European countries are struggling for the improvement of their structural macroeconomic conditions, which affect the behaviour of all economic agents. Innovations in the composition of the channels of monetary transmission might be helpful in simplifying the access to credit for households and firms, which ultimately represent the roots of a solid economic development.

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